The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
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IAEA
International Atomic Energy Agency

2053-35

Advanced Workshop on Evaluating, Monitoring and Communicating Volcanic and Seismic Hazards in East Africa

17 - 28 August 2009

Upper mantle structure beneath eastern and southern Africa: Implications for the origin of the Cenozoic rifting, volcanism and plateau uplift

Andy Nyblade
Pennsylvania State University, University Park
USA

Upper mantle structure beneath eastern, southern and central Africa: Implications for the origin of Cenozoic rifting, volcanism and plateau uplift

Andy Nyblade, Department of Geosciences, Penn State University, University Park, PA 16802 USA

Advanced workshop on evaluating, monitoring and communicating volcanic and seismic hazards in East Africa

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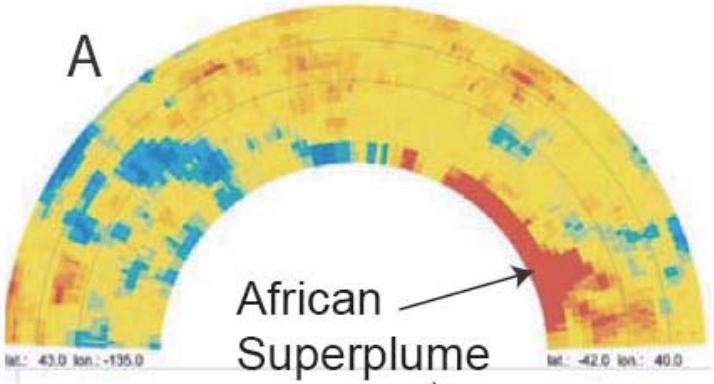
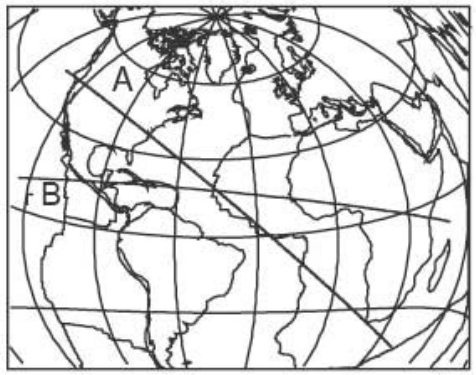
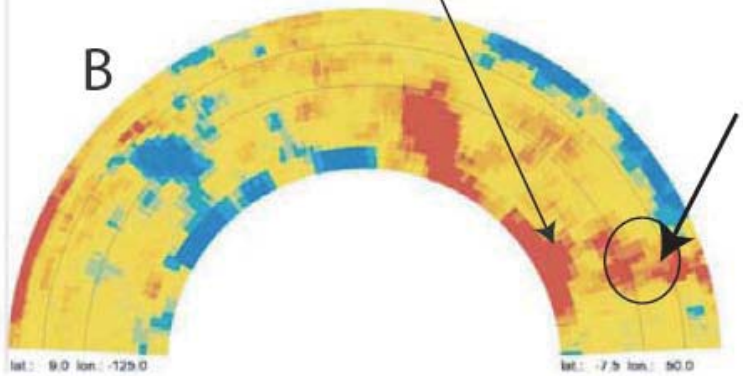
Trieste, Italy

Collaborators: Addis Ababa University, KenGen, University of Nairobi, University of Dar es Salaam, Tanzania Geological Survey, IRGM, University of Yaounde



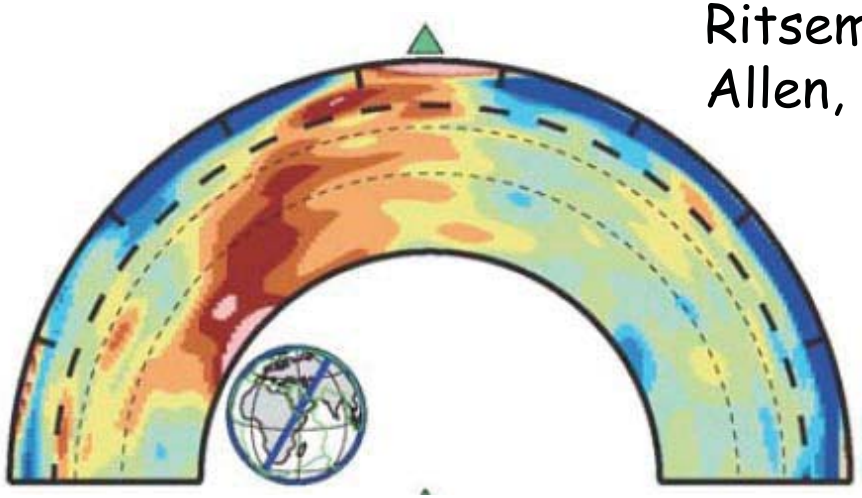


Grand, 2002

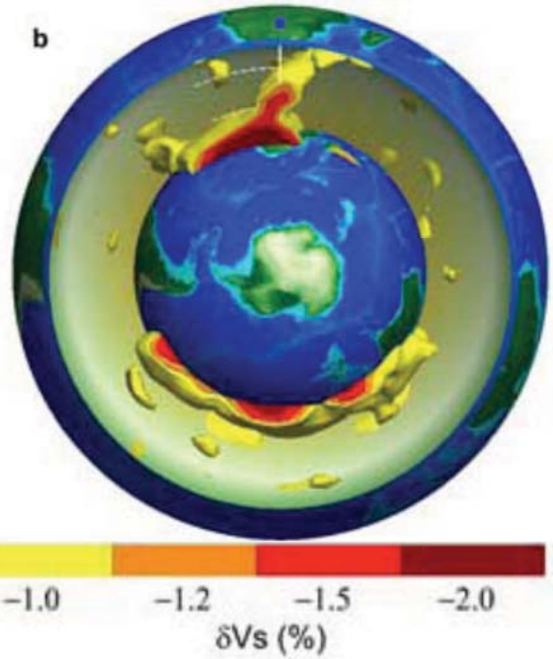


region in mid-mantle where connection is suggested between lower and upper mantle structure

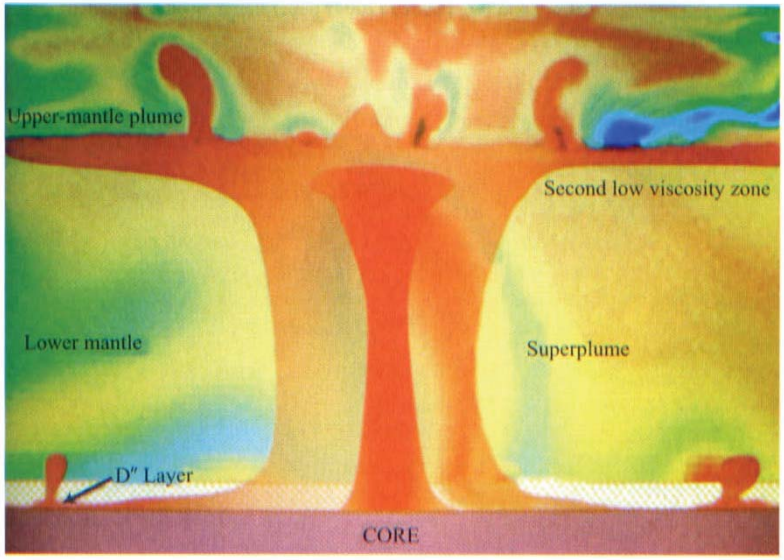
Simmons et al., 2007



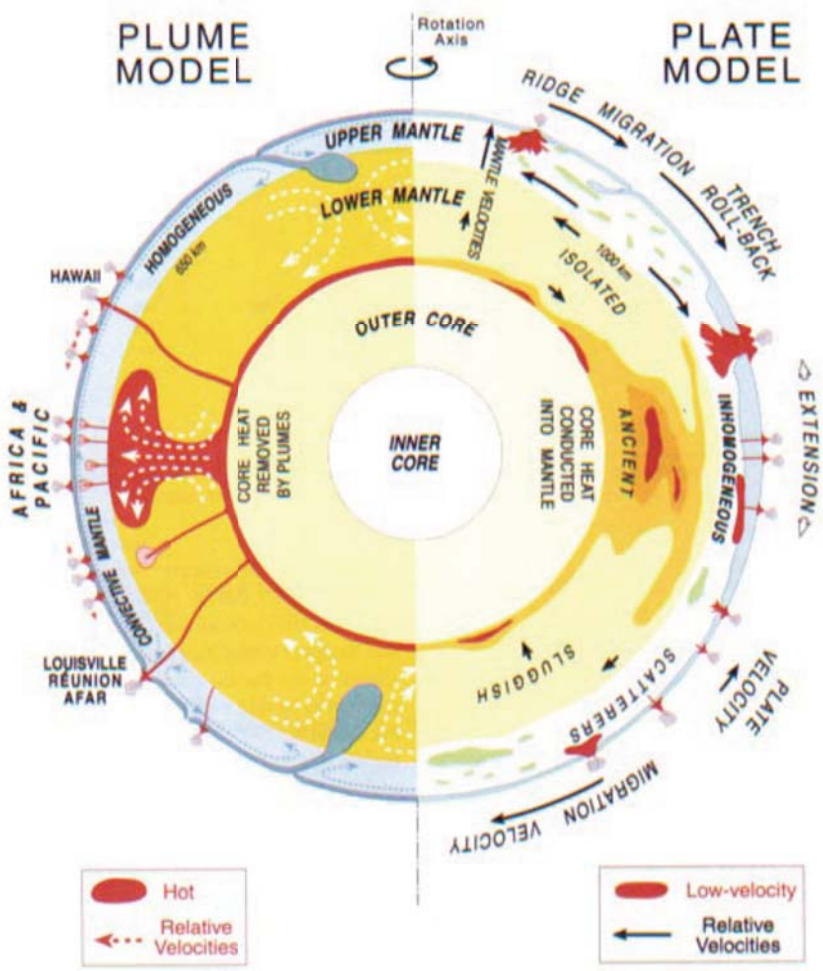
Ritsema and Allen, 2003

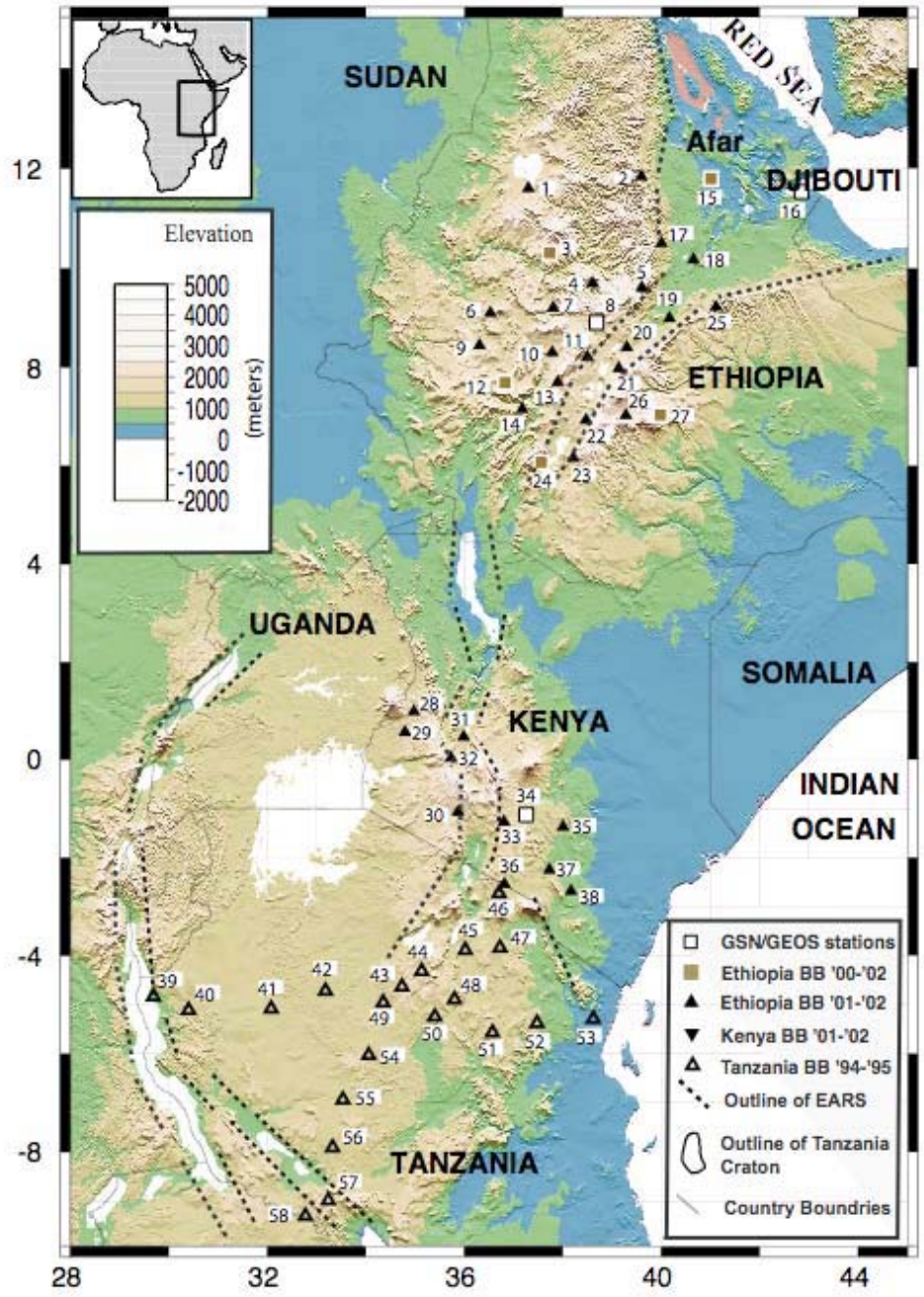


Plume vs Plate Model (Anderson, 2005)



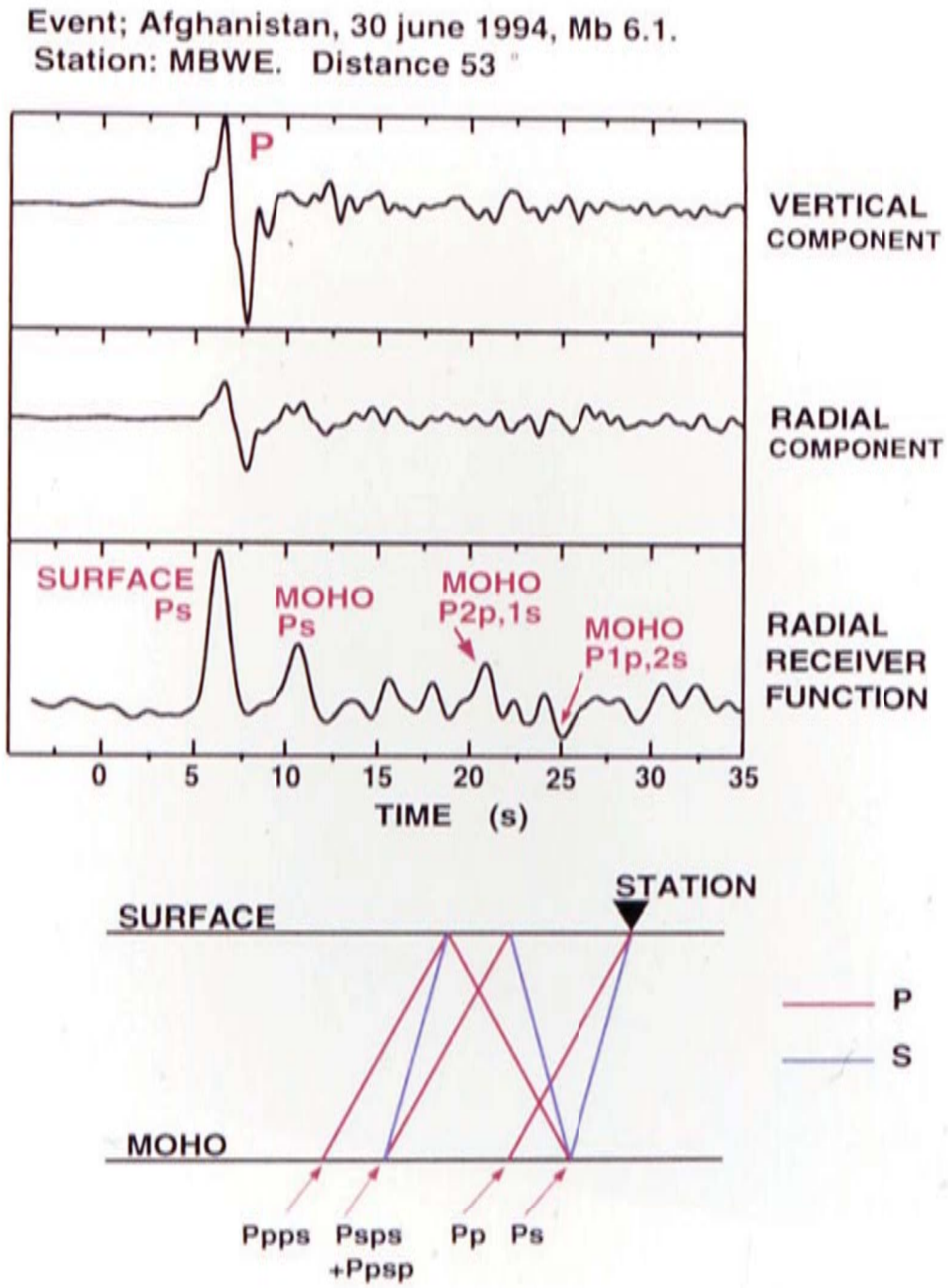
Yuen et al., 2007

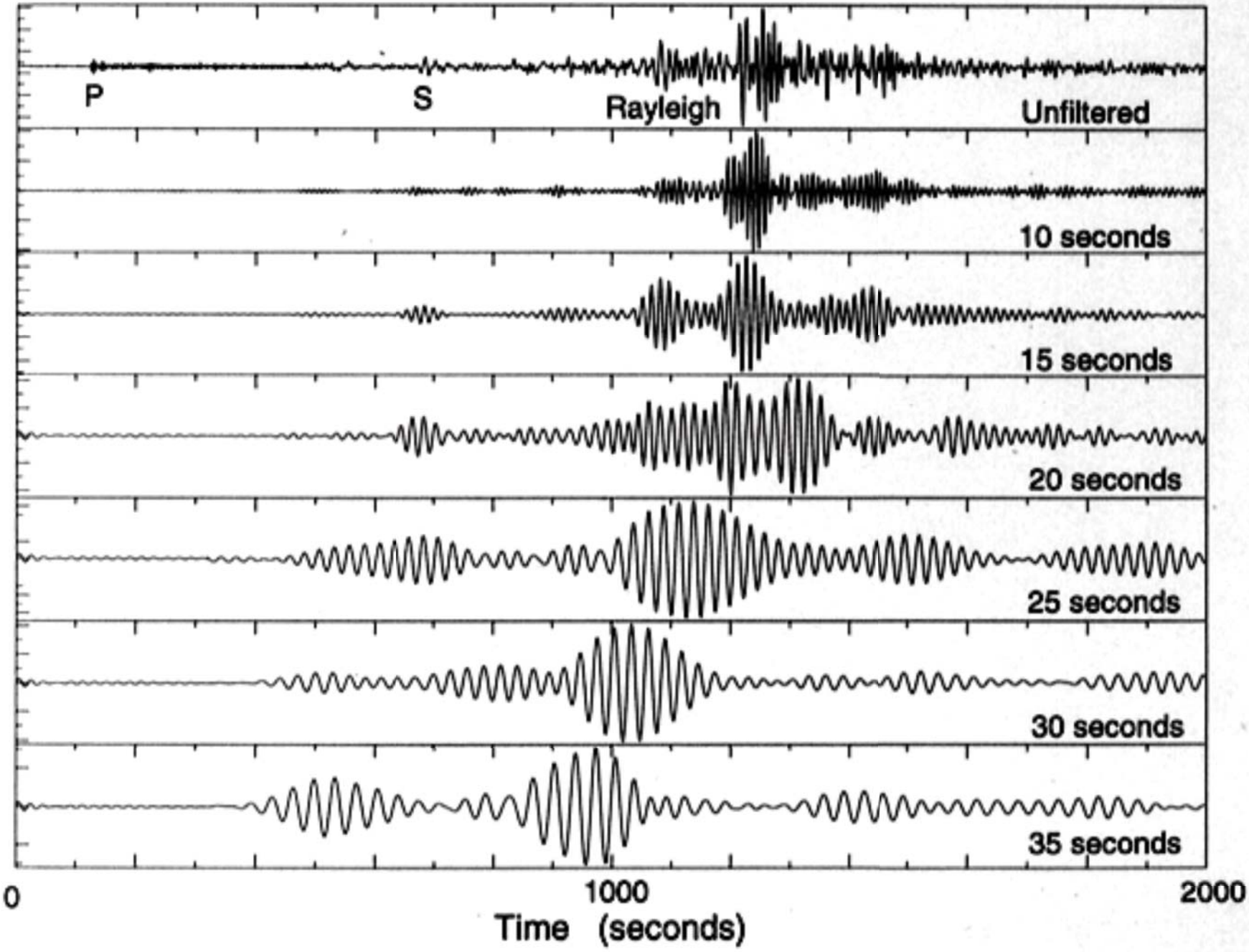


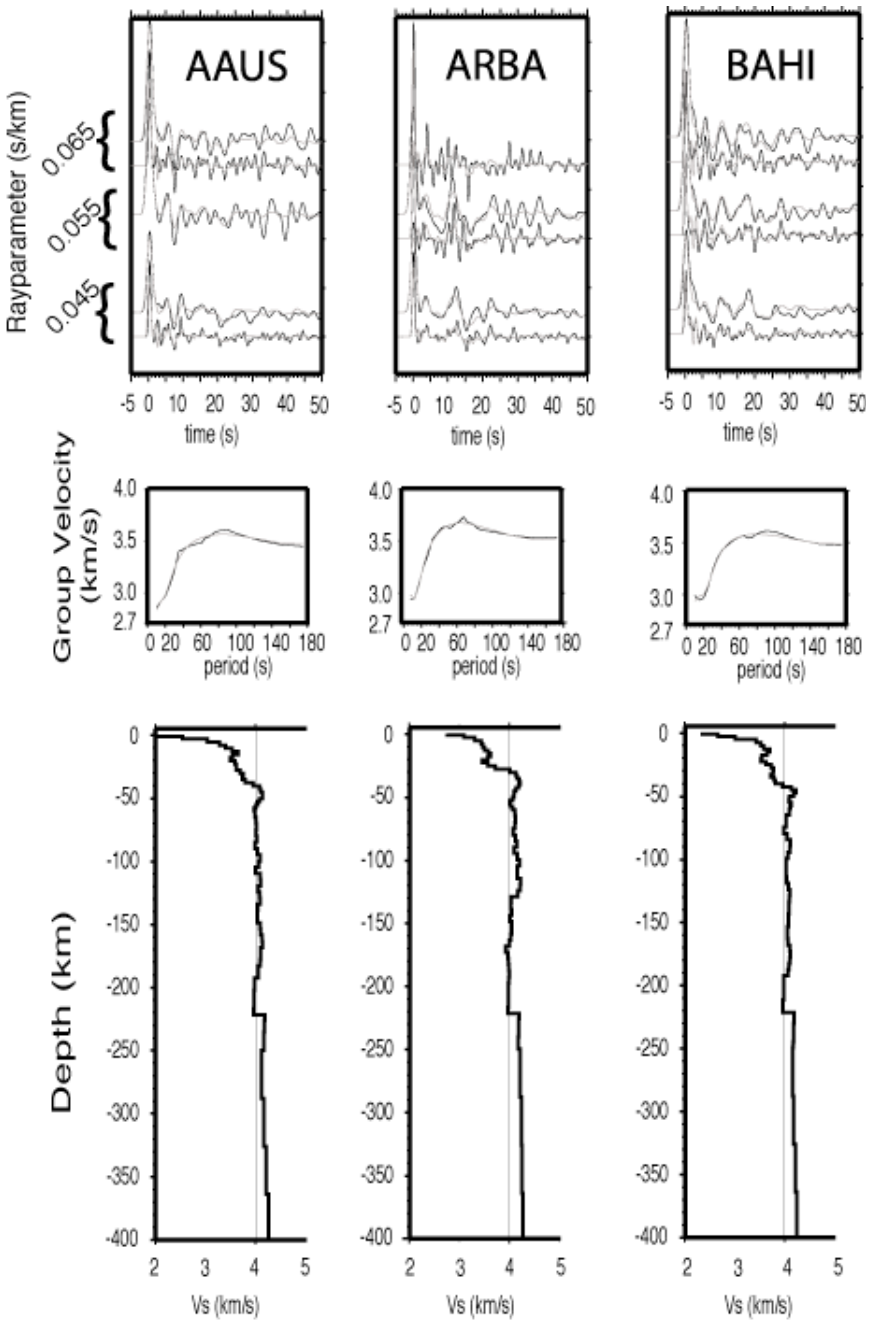


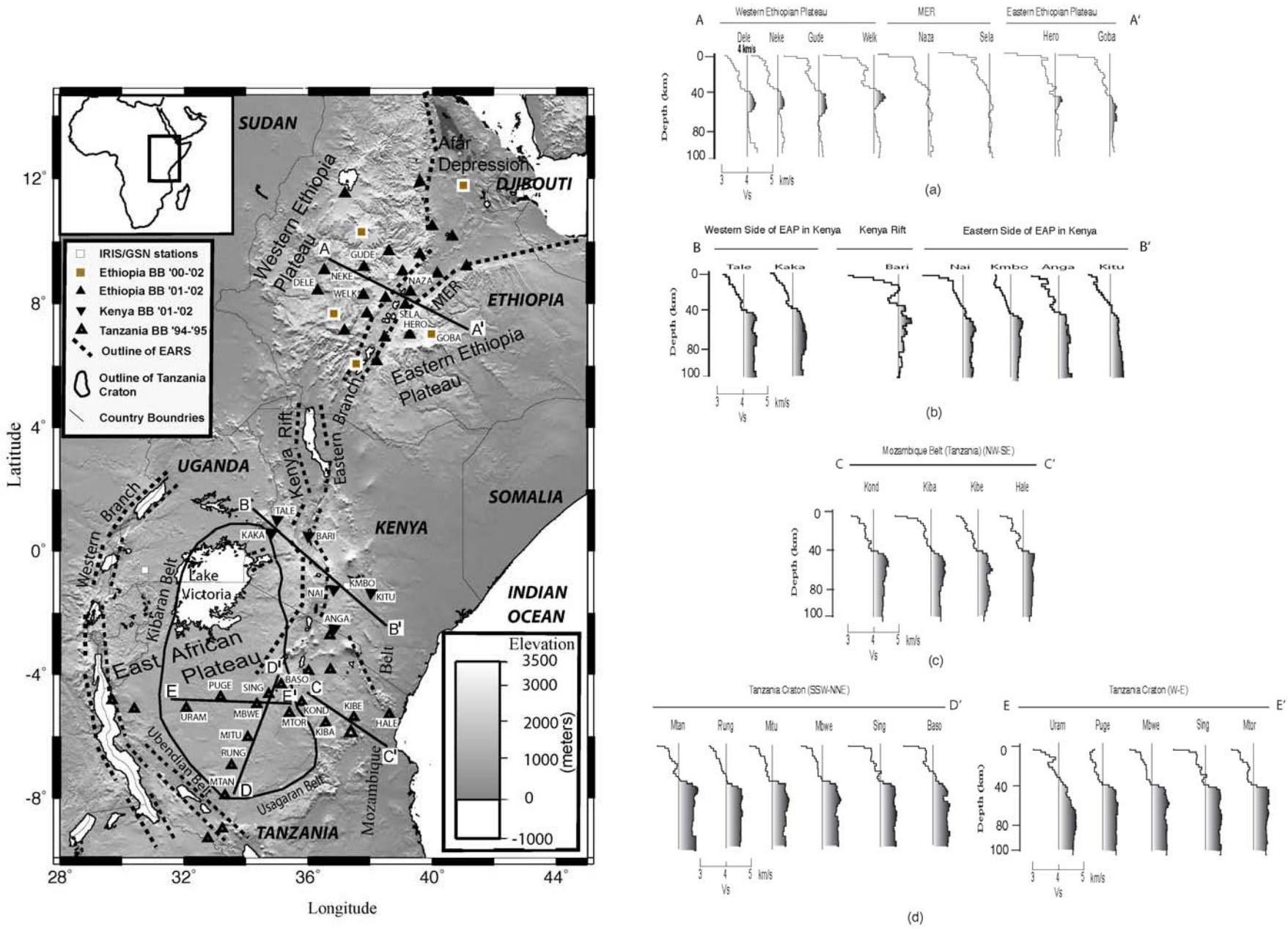
Broadband Seismic Experiments in Eastern Africa

- Joint inversion of Rec. functions and surface wave group velocities
- Body wave travel time tomography
- 410 and 660 km discontinuity structure from rec. functions


Event; Afghanistan, 30 june 1994, Mb 6.1.
Station: MBWE. Distance 53 °
P
VERTICAL COMPONENT
RADIAL COMPONENT
SURFACE Ps
MOHO Ps
MOHO P2p,1s
MOHO P1p,2s
RADIAL RECEIVER FUNCTION
0 5 10 15 20 25 30 35
TIME (s)
STATION
SURFACE
MOHO
P
S
Ppps
Psps +Ppsp
Pp
Ps


P
S
Rayleigh
Unfiltered
10 seconds
15 seconds
20 seconds
25 seconds
30 seconds
35 seconds
0
1000
2000
Time (seconds)

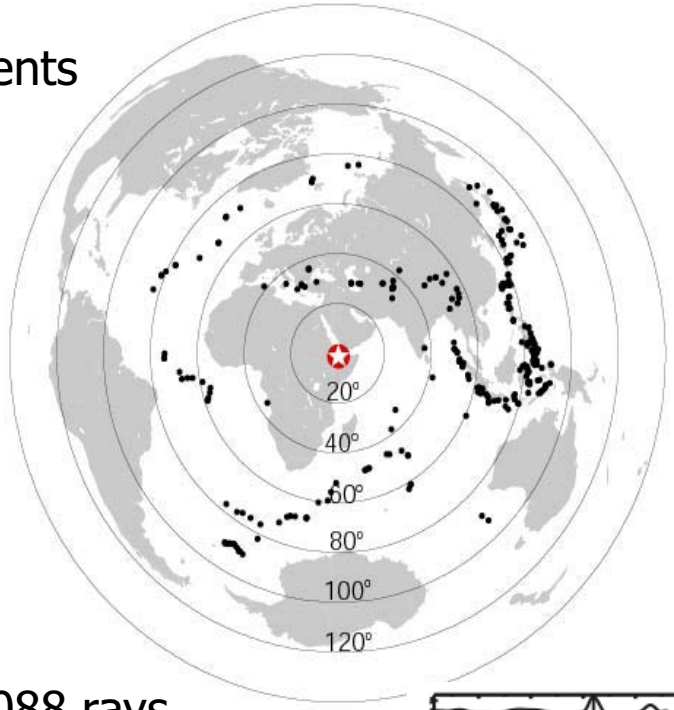

AAUS
ARBA
BAHI
Rayparameter (s/km)
0.065
0.055
0.045
-5 0 10 20 30 40 50
time (s)
Group Velocity (km/s)
4.0
3.5
3.0
2.7
0 20 60 100 140 180
period (s)
Depth (km)
0
-50
-100
-150
-200
-250
-300
-350
-400
2 3 4 5
Vs (km/s)



Dugda et al., 2007; Dugda & Nyblade, 2009; Julia et al., 2005

Event Locations - Ethiopia

P events

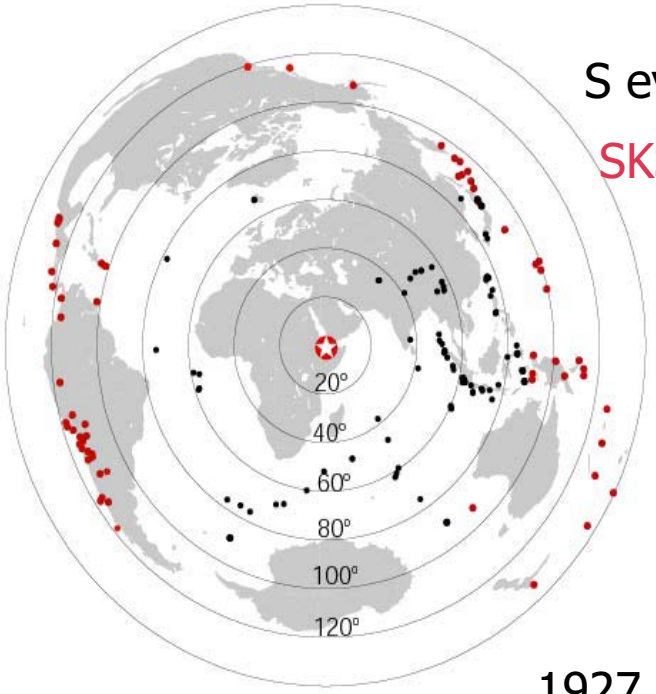


3088 rays

300 events

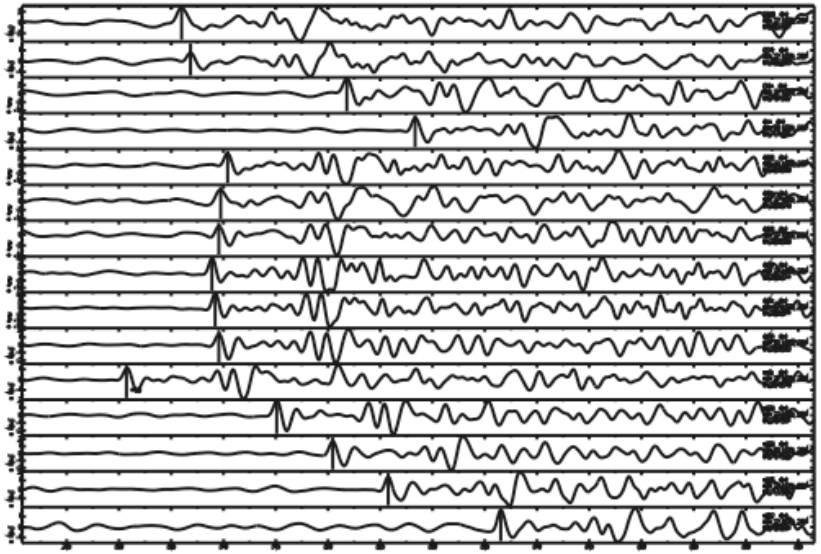
S events

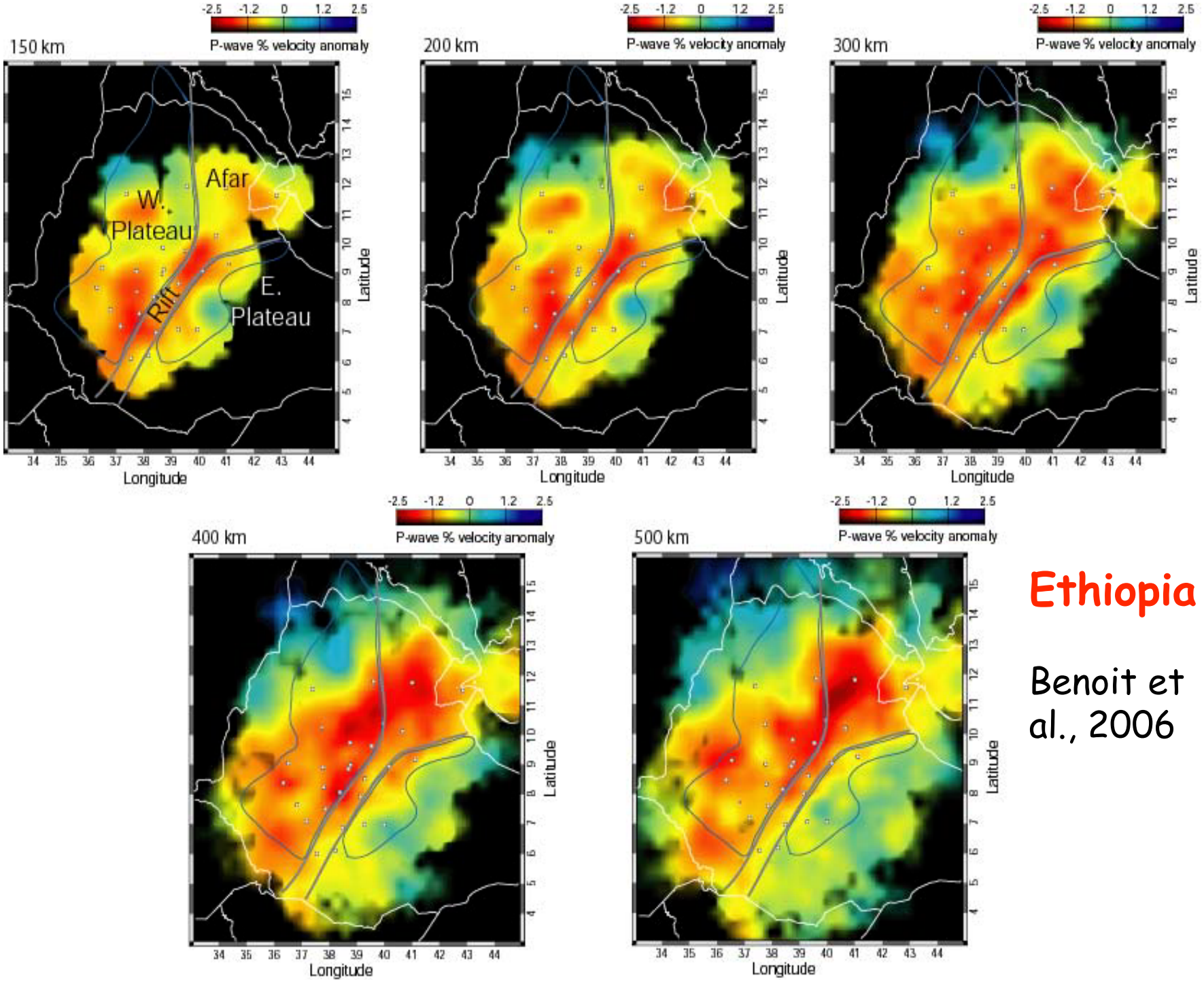
SKS events



1927 rays

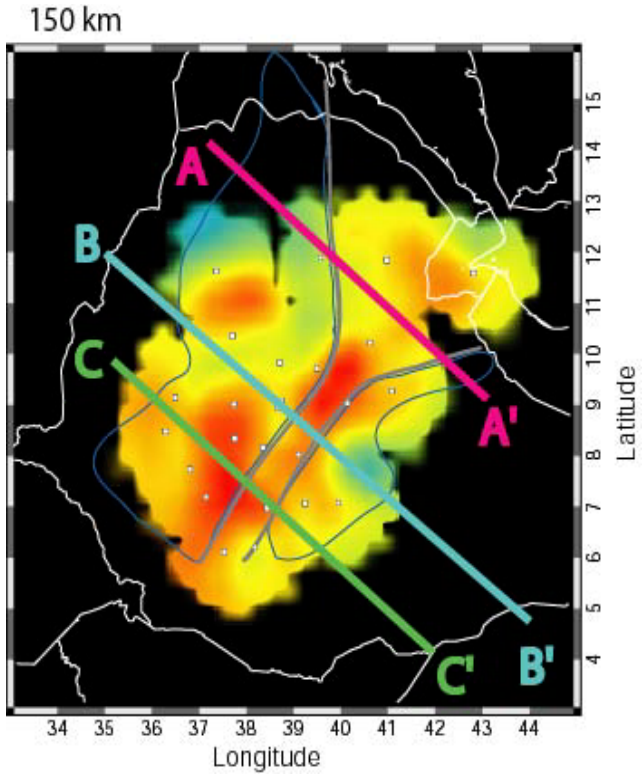
196 events

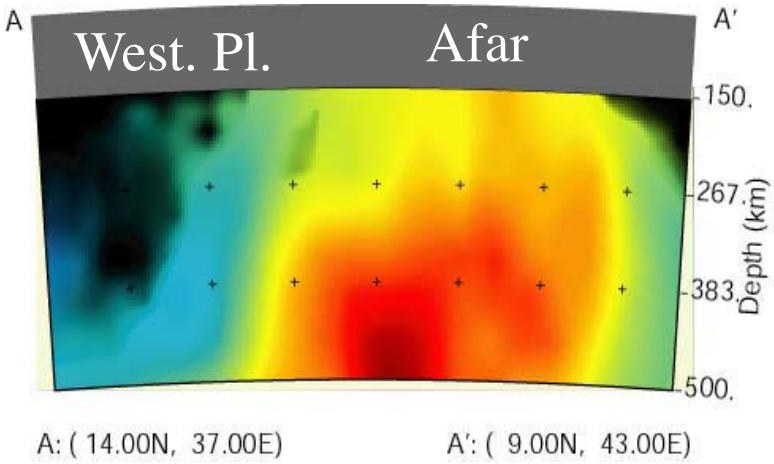




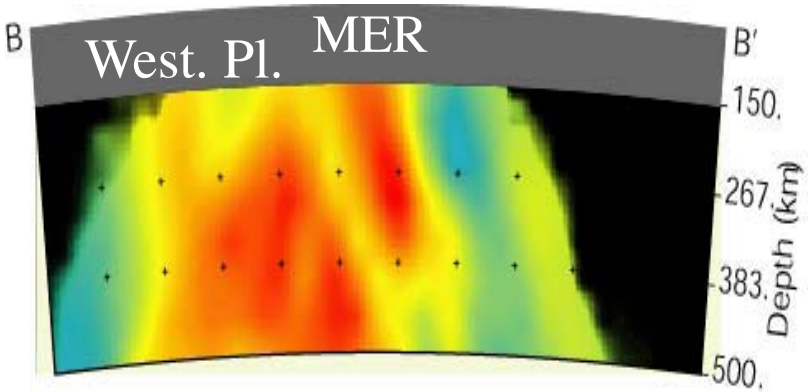
Ethiopia

Benoit et al., 2006

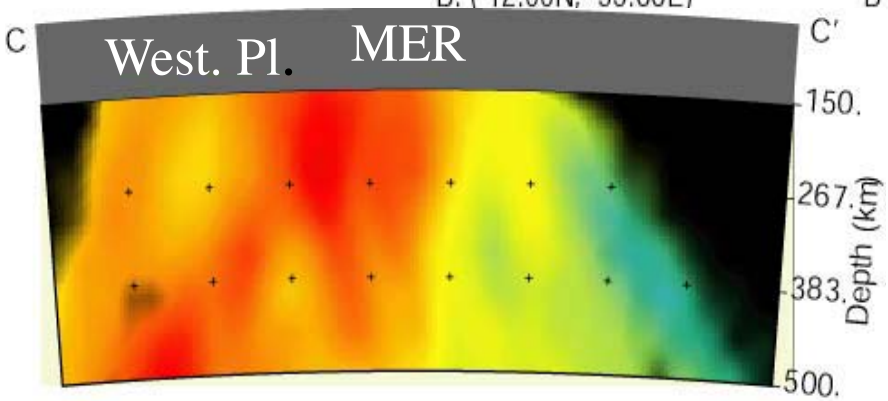




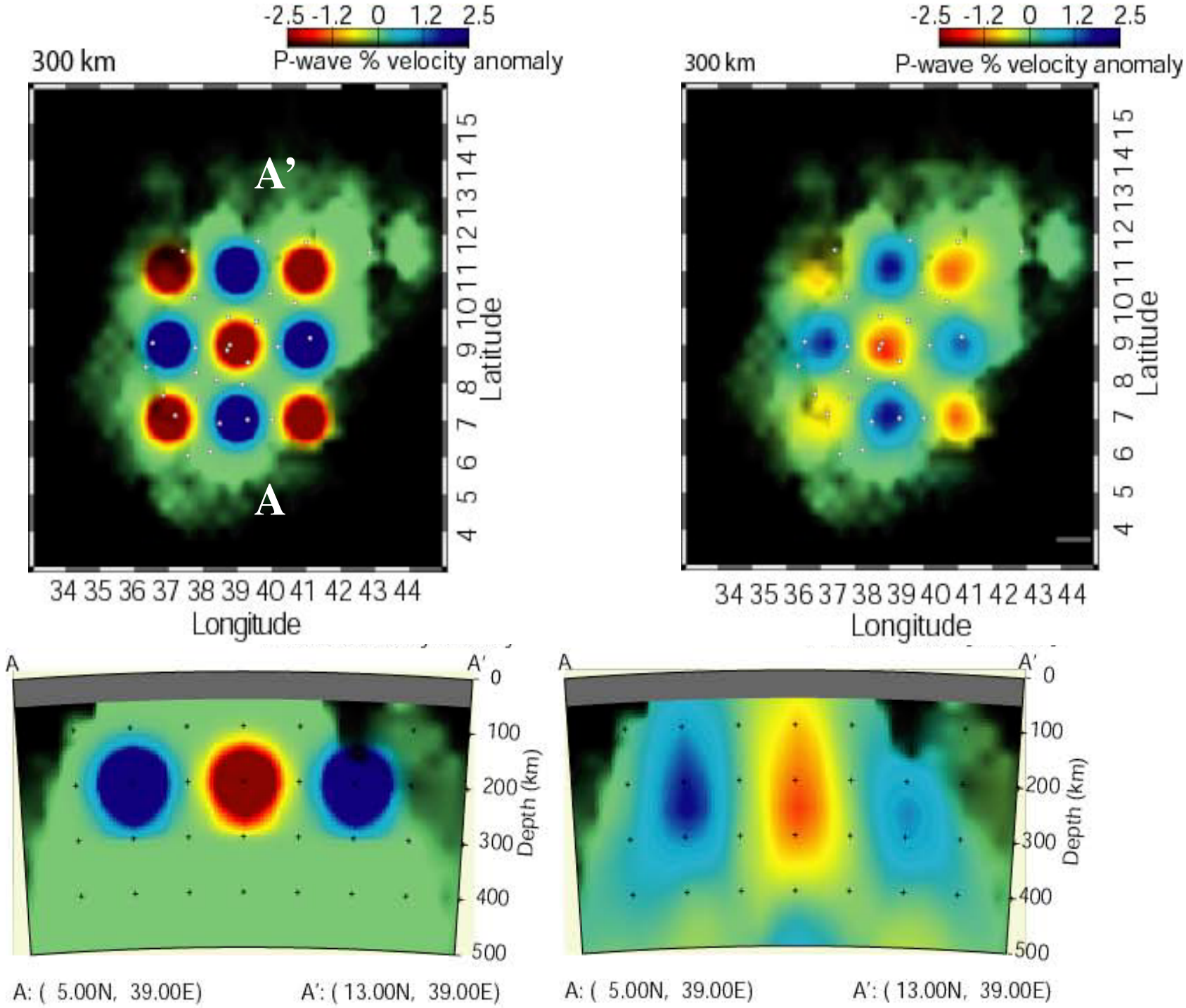
A: (14.00N, 37.00E) A': (9.00N, 43.00E)



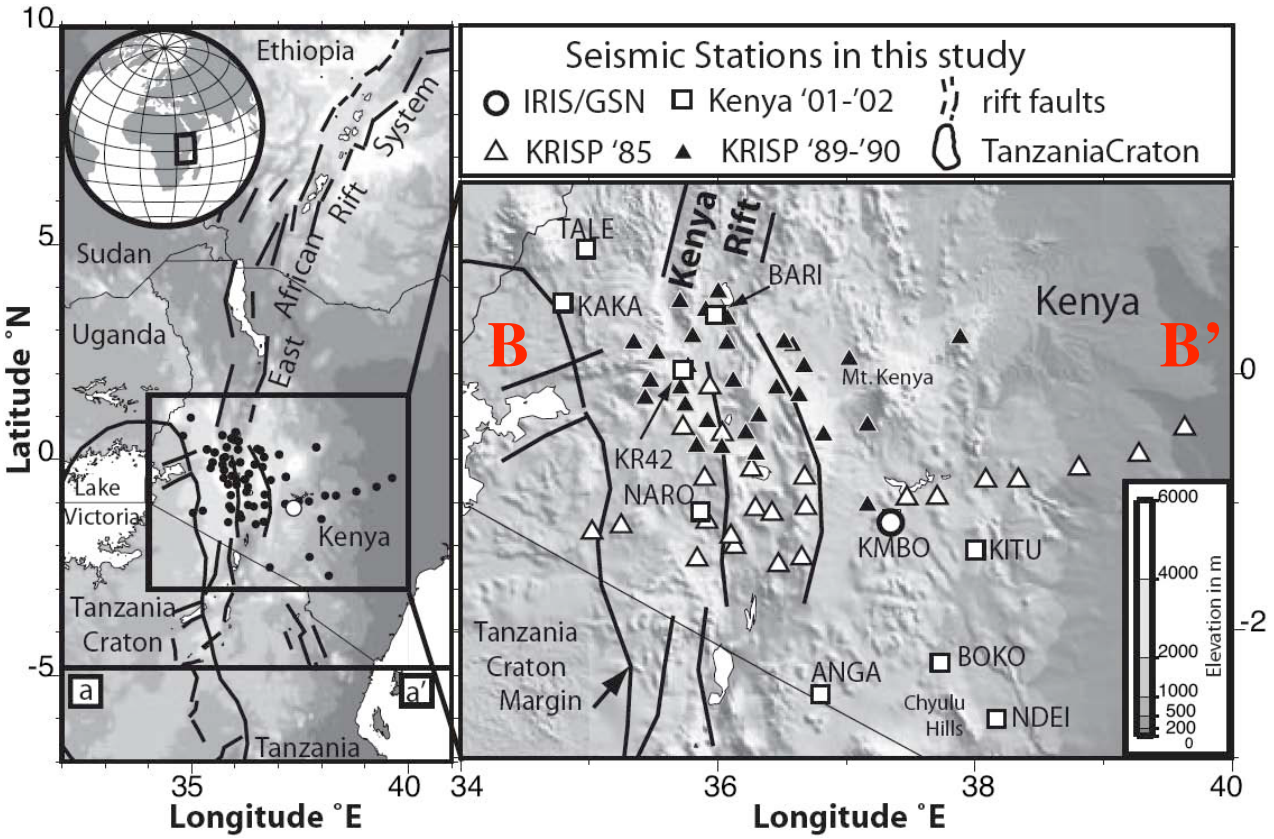
B: (12.00N, 35.00E) B': (5.00N, 44.00E)



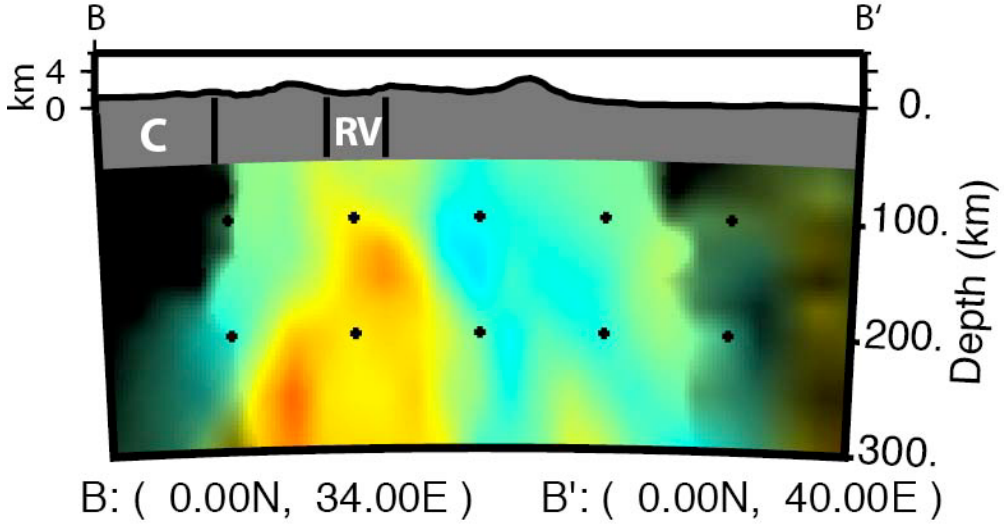
C: (10.00N, 35.00E) C': (4.00N, 42.00E)

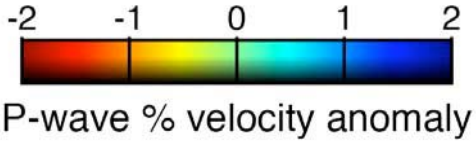

-2.5 -1.2 0 1.2 2.5
P-wave % velocity anomaly
300 km
A'
A
4 5 6 7 8 9 10 11 12 13 14 15
Latitude
34 35 36 37 38 39 40 41 42 43 44
Longitude
-2.5 -1.2 0 1.2 2.5
P-wave % velocity anomaly
300 km
4 5 6 7 8 9 10 11 12 13 14 15
Latitude
34 35 36 37 38 39 40 41 42 43 44
Longitude
A
A'
0
100
200
300
400
500
Depth (km)
A: (5.00N, 39.00E)
A': (13.00N, 39.00E)
A
A'
0
100
200
300
400
500
Depth (km)
A: (5.00N, 39.00E)
A': (13.00N, 39.00E)

Kenya

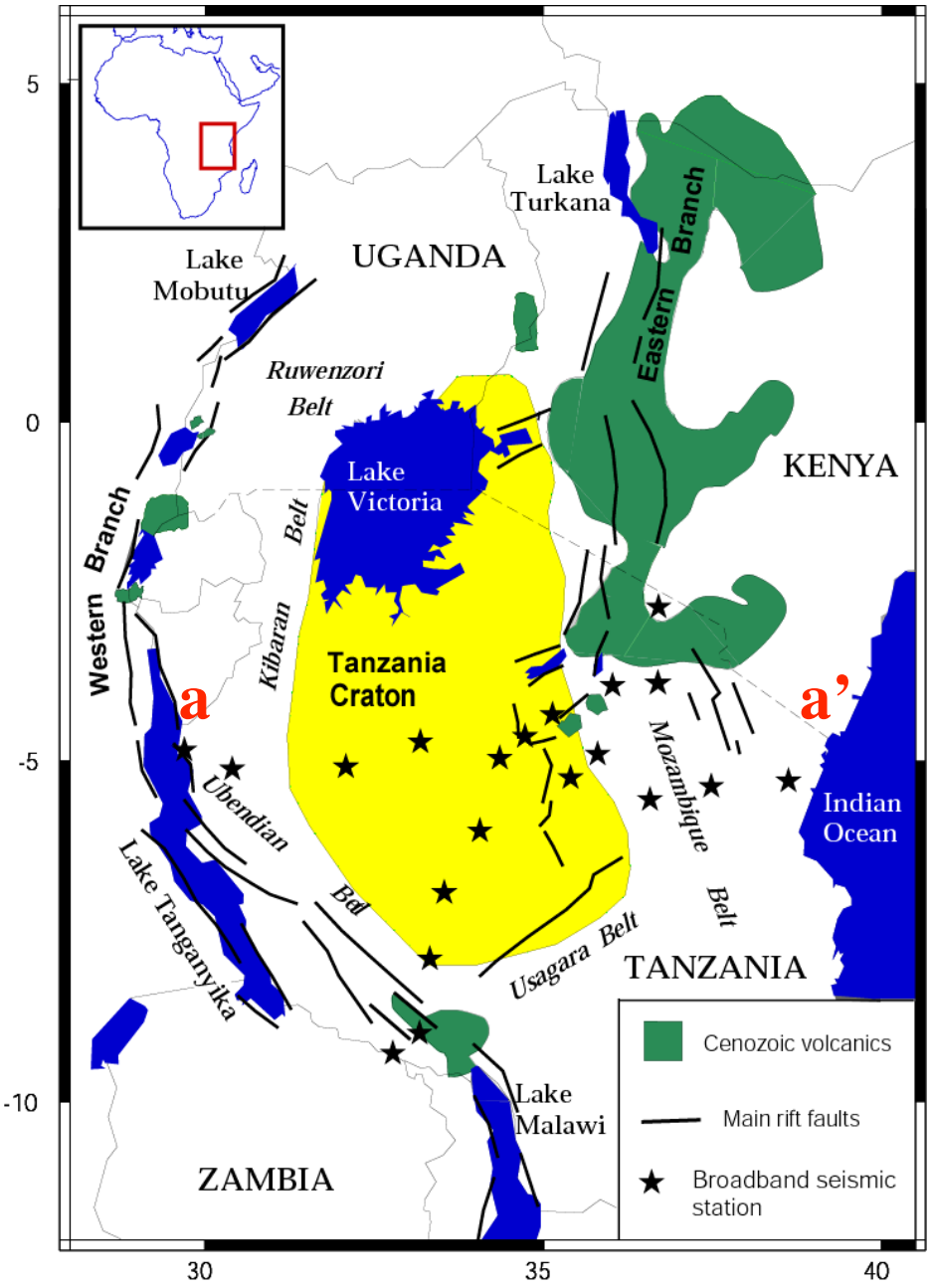


Park and Nyblade (2006)

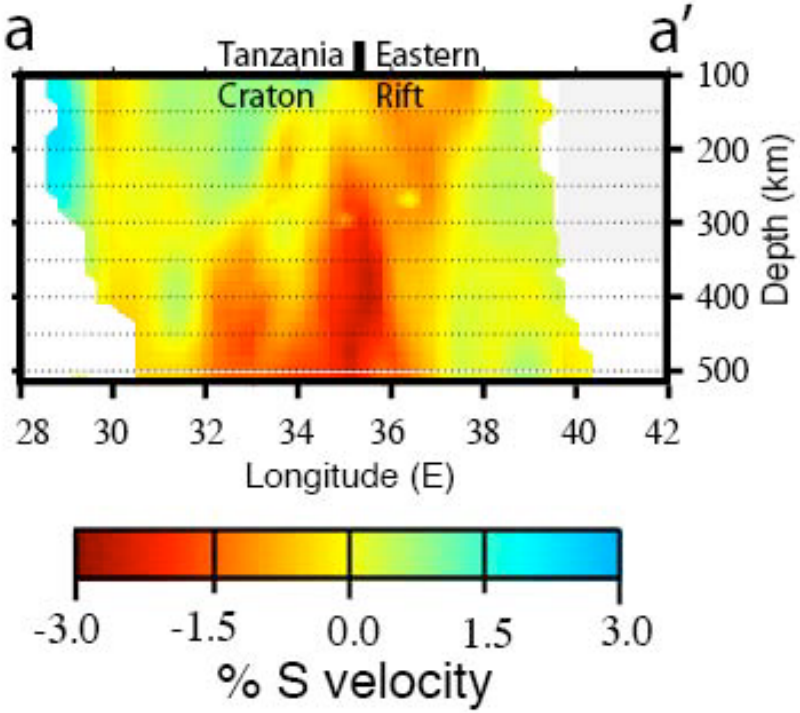


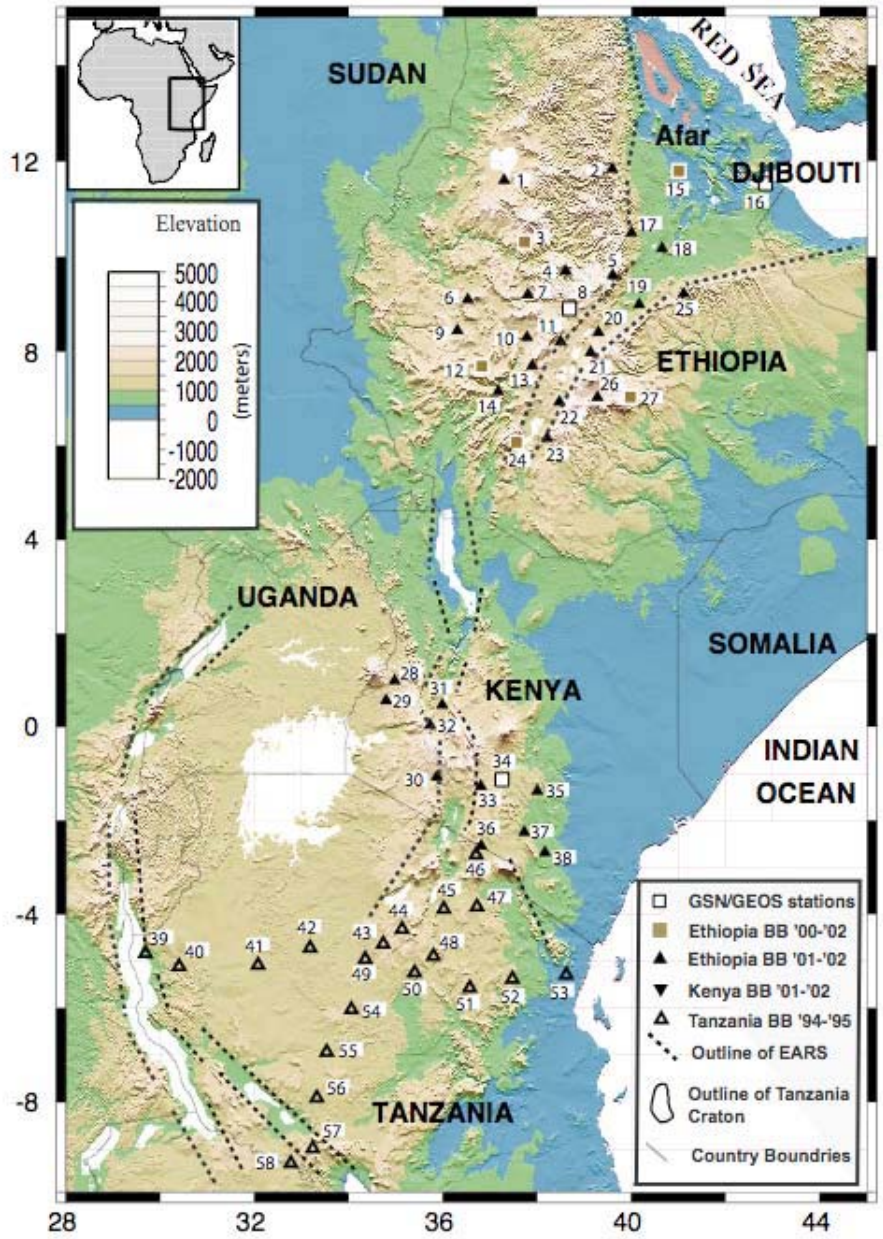


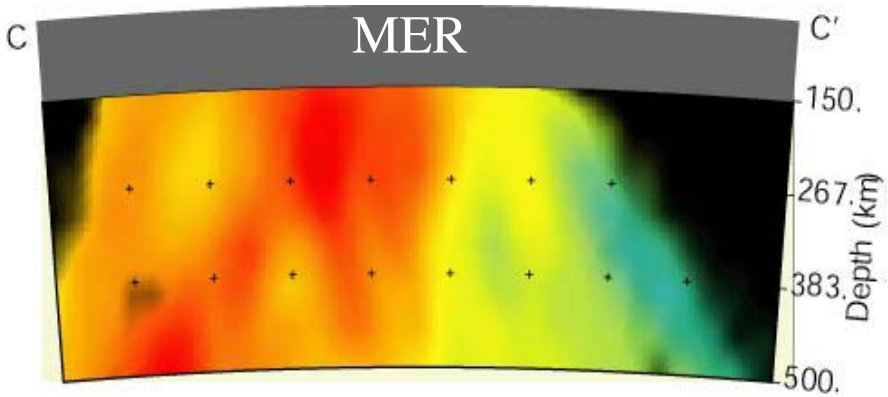
Tanzania



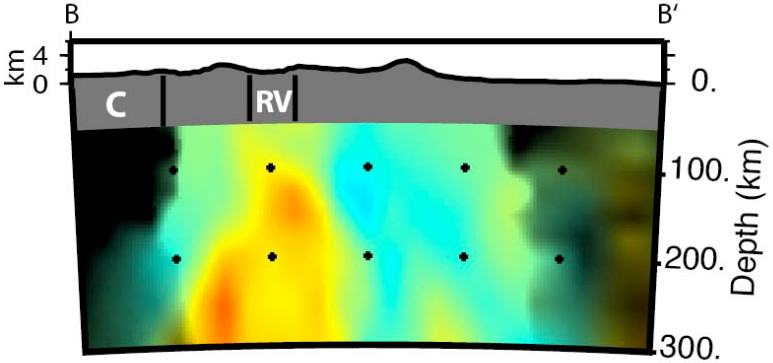
Ritsema et al. (1998)



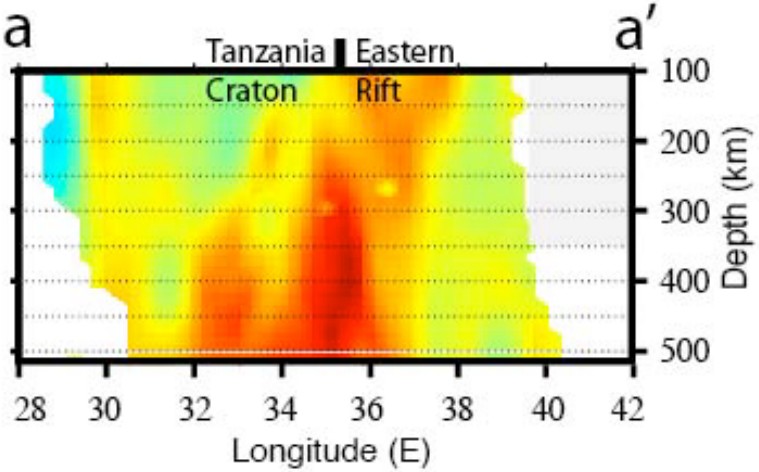




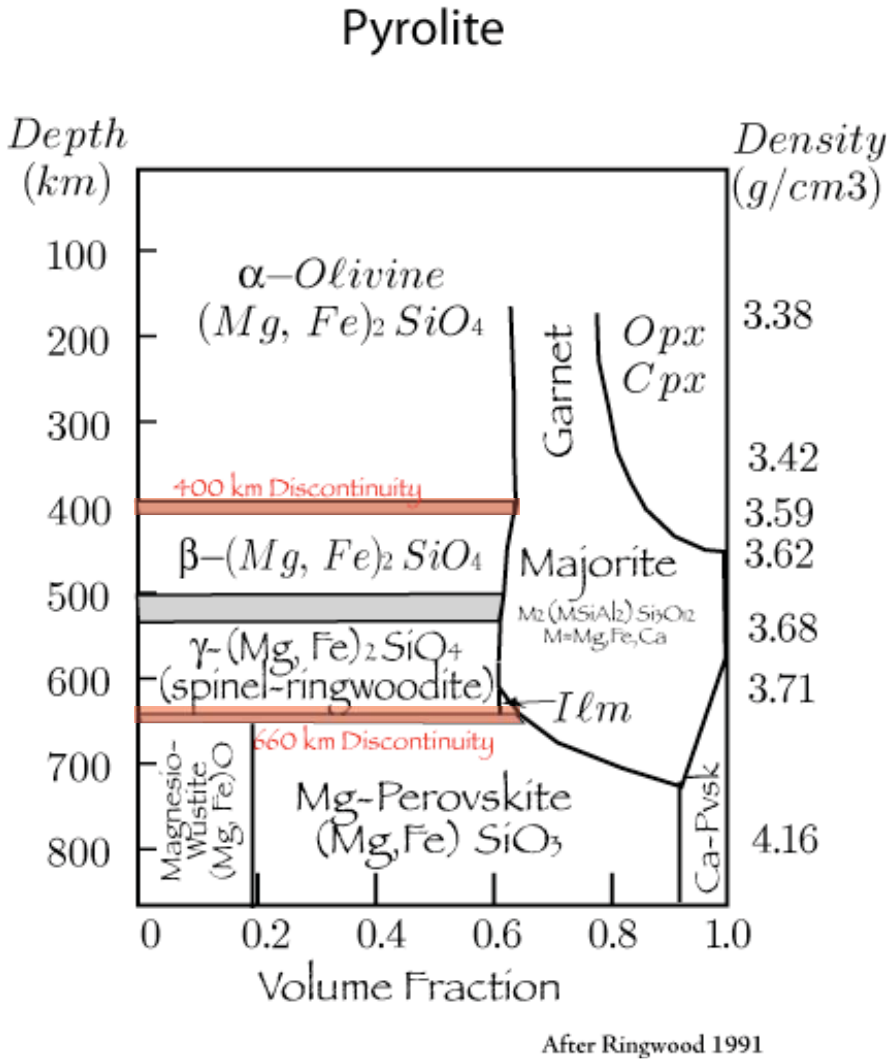
C: (10.00N, 35.00E) C': (4.00N, 42.00E)

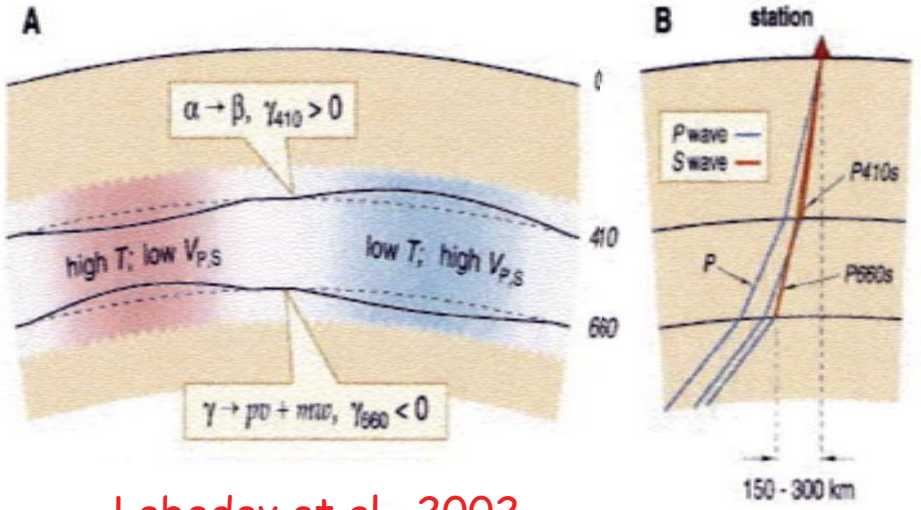


B: (0.00N, 34.00E) B': (0.00N, 40.00E)



Using topography on mantle transition zone discontinuities to reveal temperature anomalies



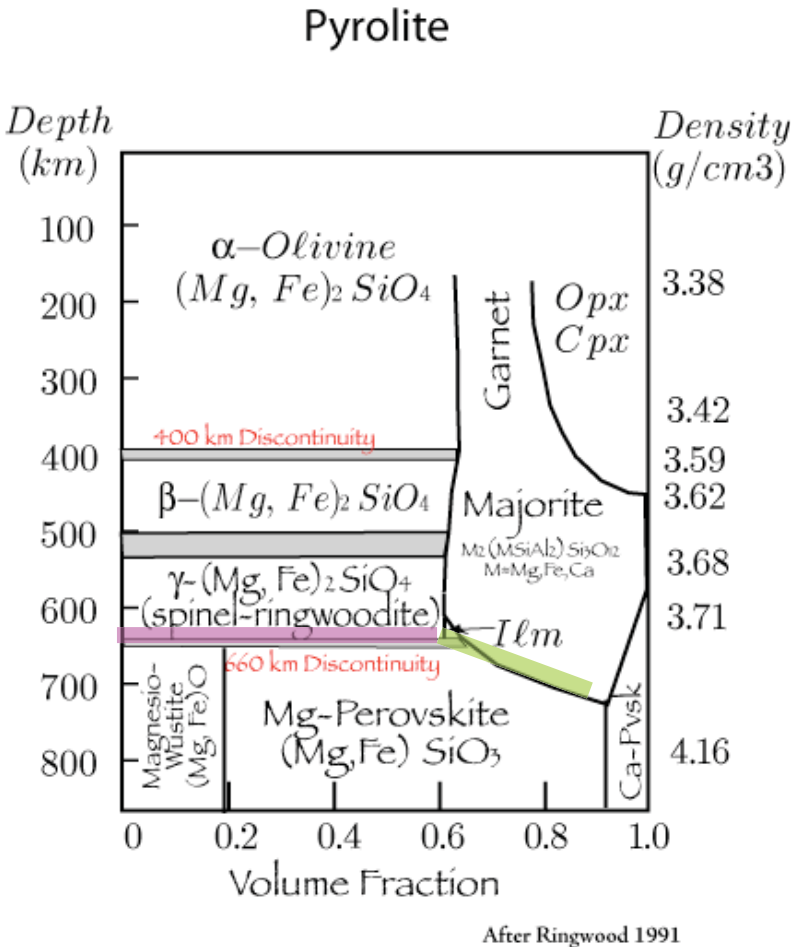


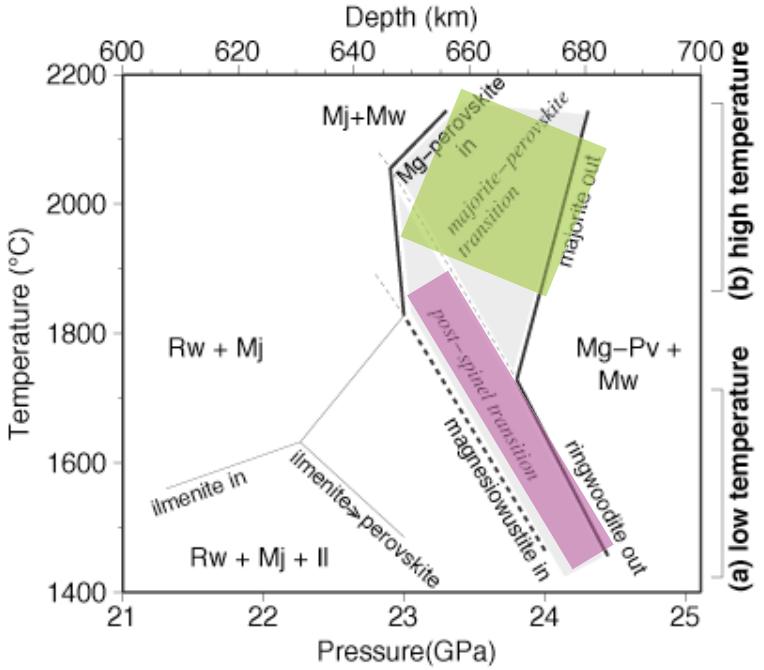
Lebedev et al., 2002

Other phase changes near 660 km

- Majorite ->Perovskite transition

positive Clapeyron Slope

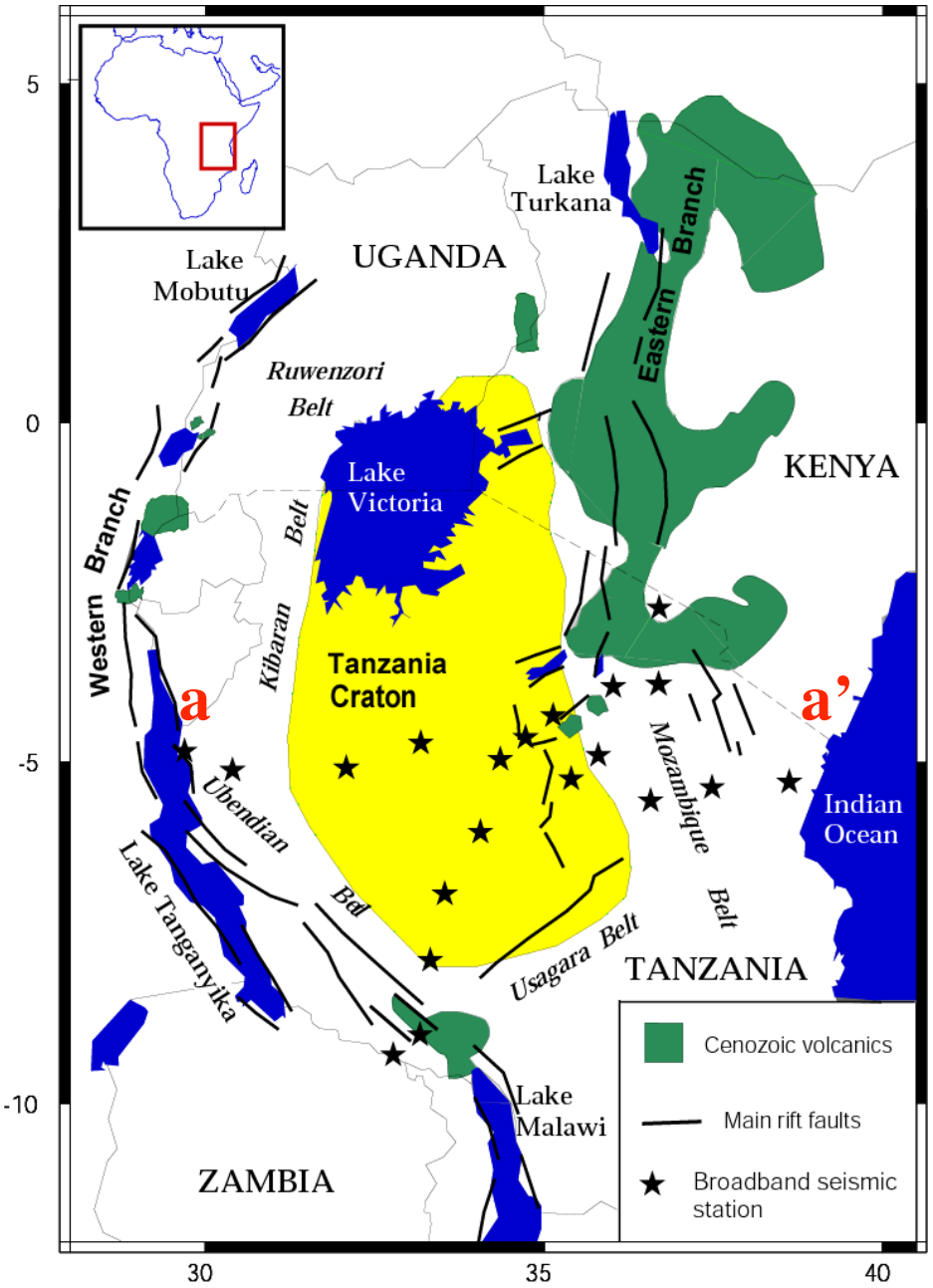


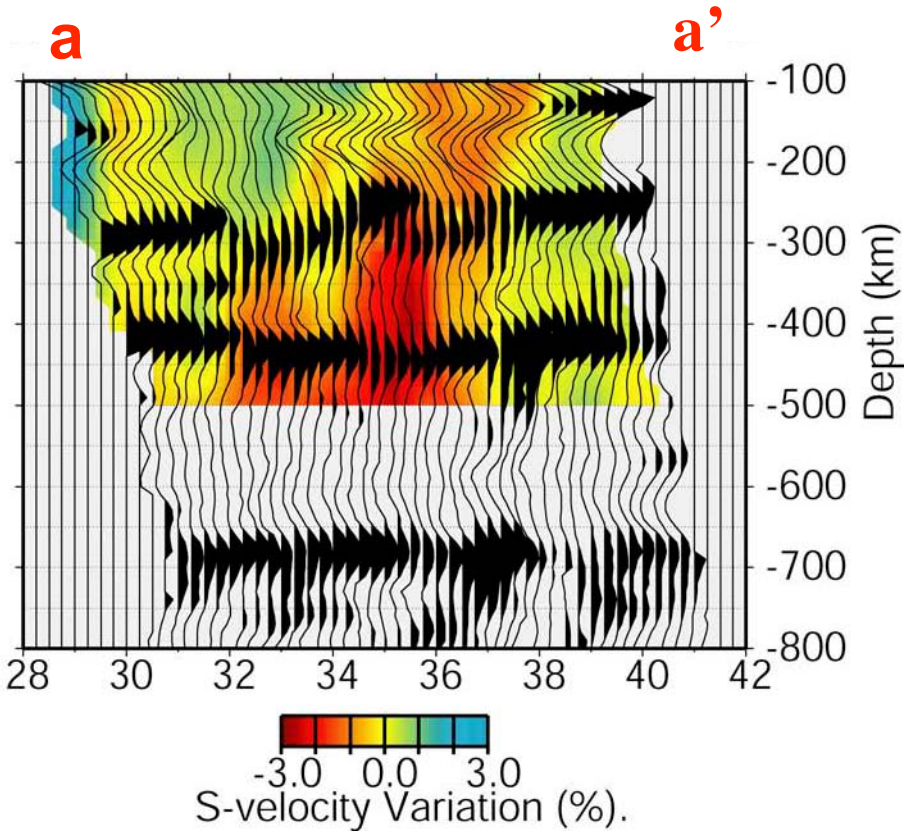


Deuss et al, 2007 (adapted from Hirose, 2002)

Weidner and Wang, 1998; Hirose, 2002

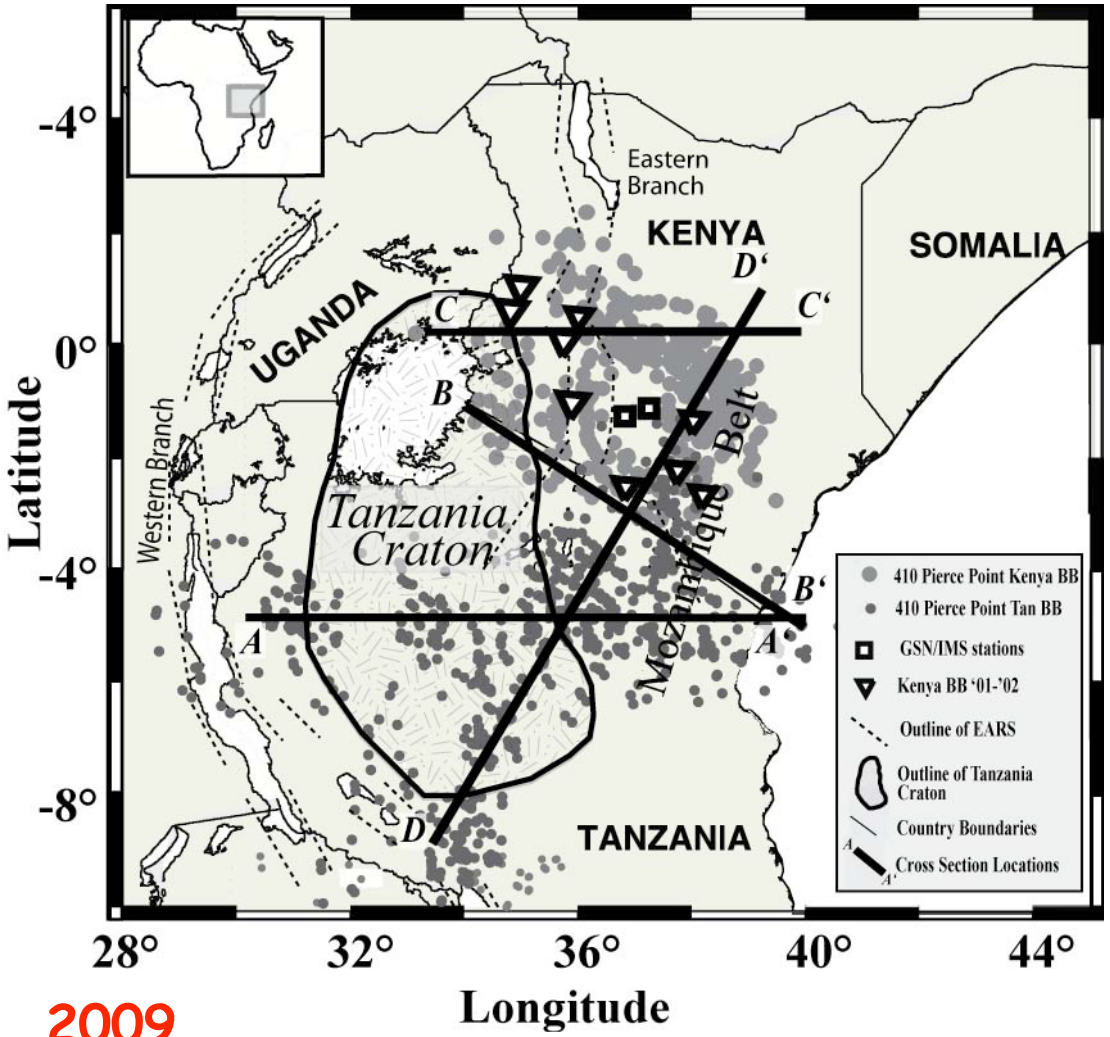
Tanzania





Owens et al. (2000)

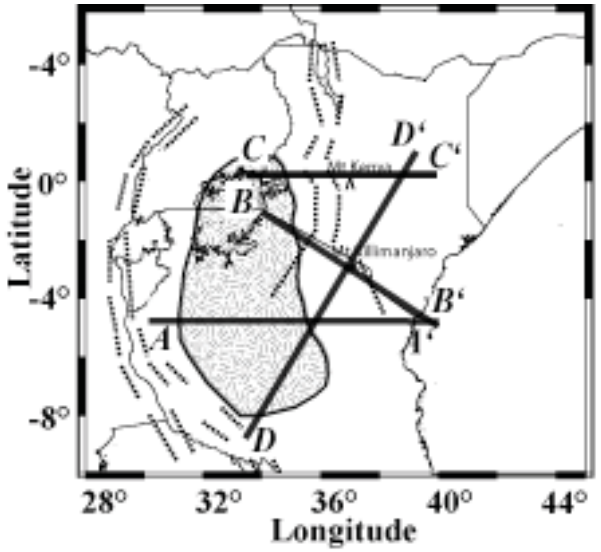
Kenya-Tanzania: Station locations and "410" pierce points

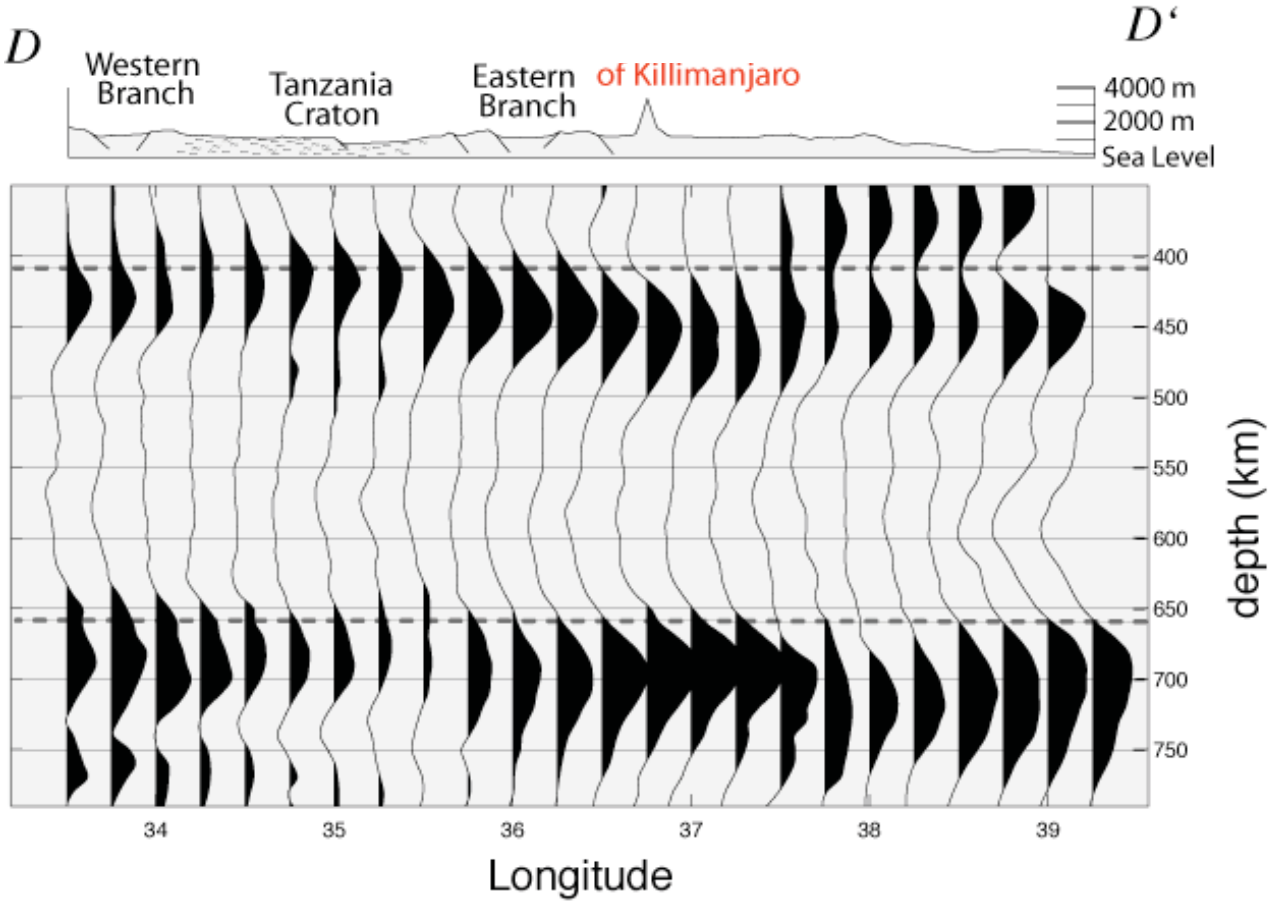


Huerta et al., 2009

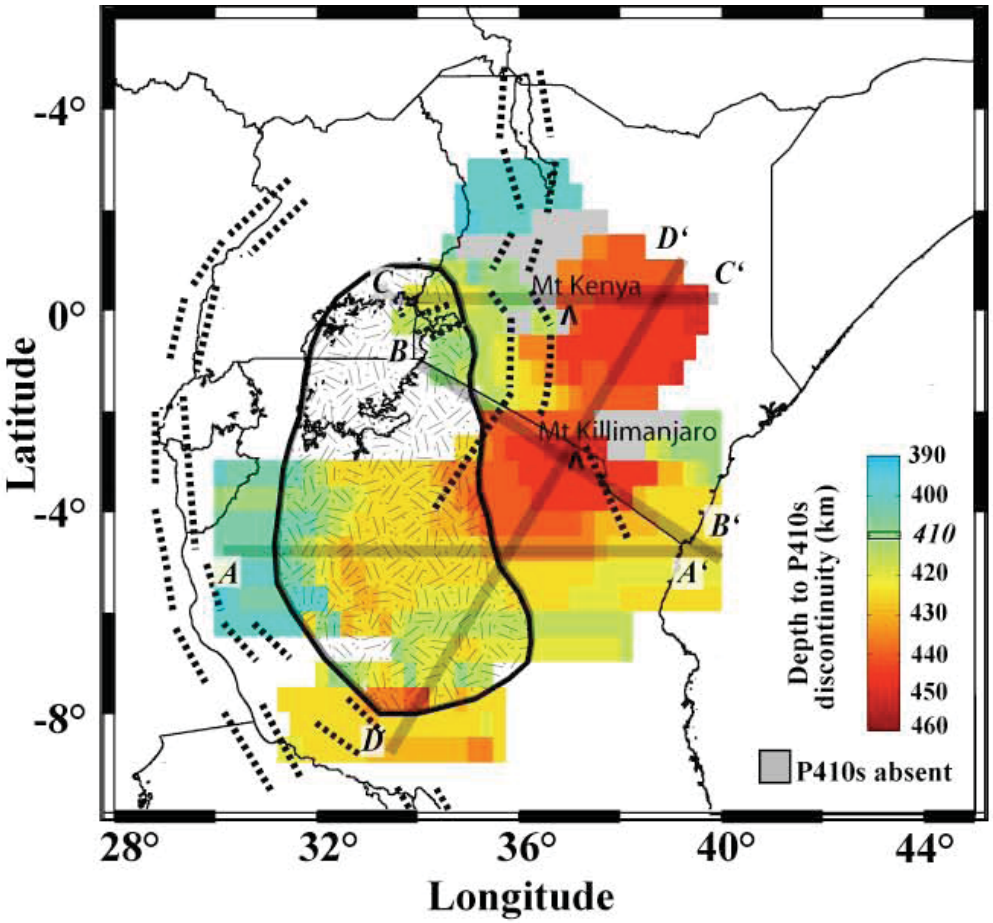
Results

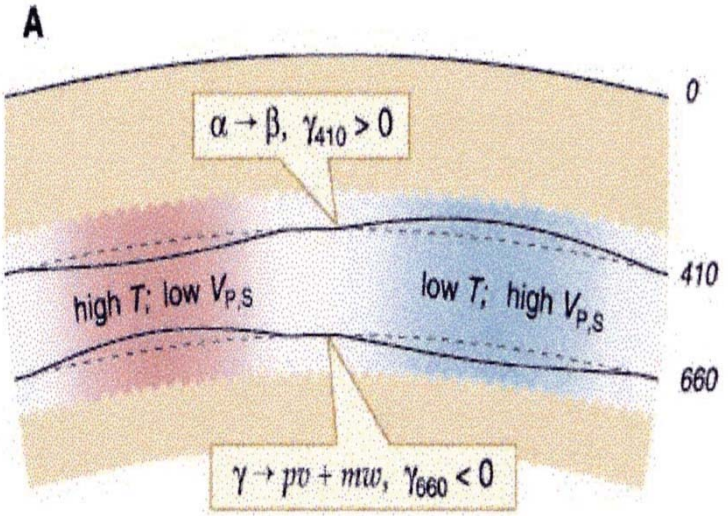
- Normal "410" beneath Craton
- Depressed "410" beneath rift and volcanic fields

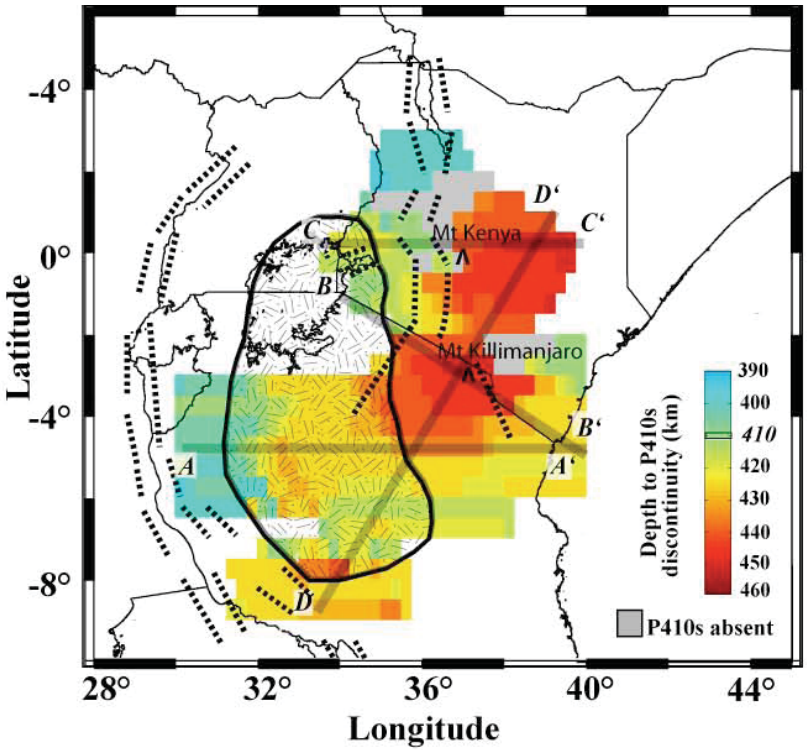


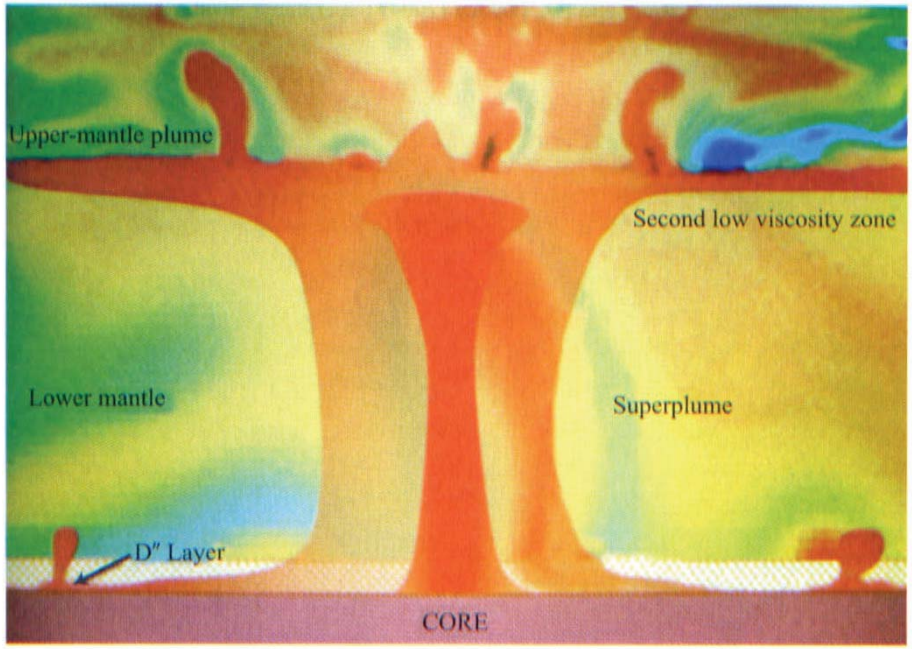


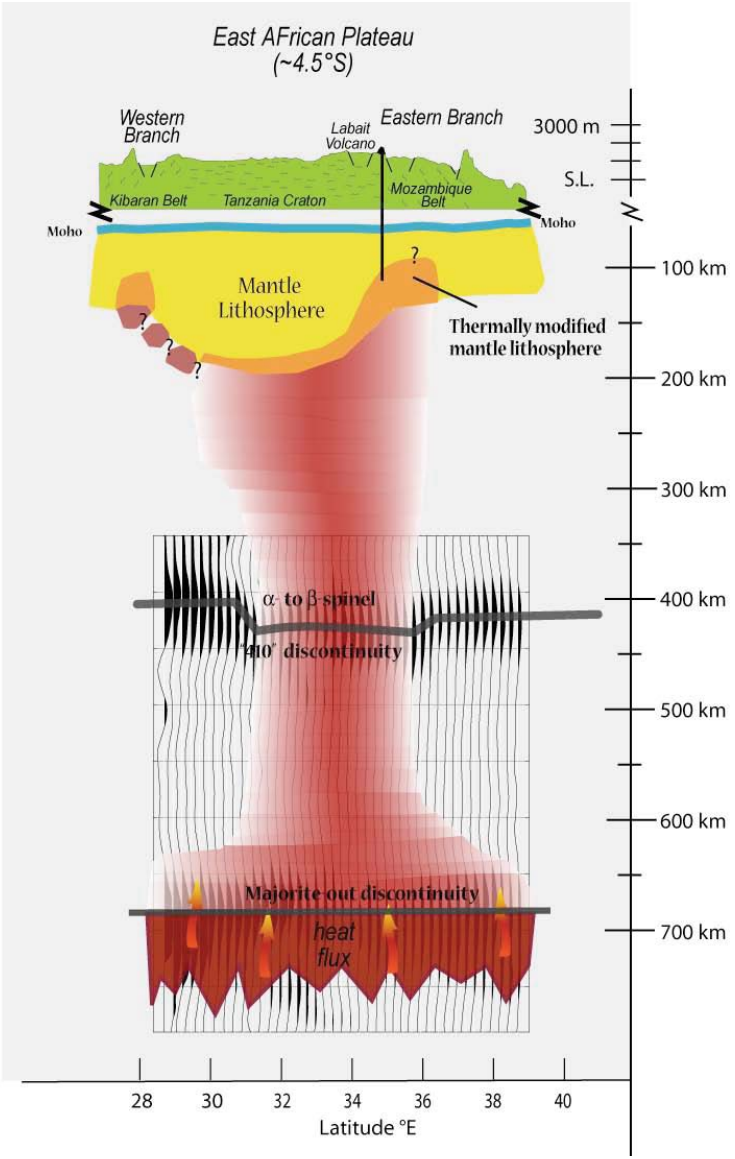
Depth to “410” Discontinuity

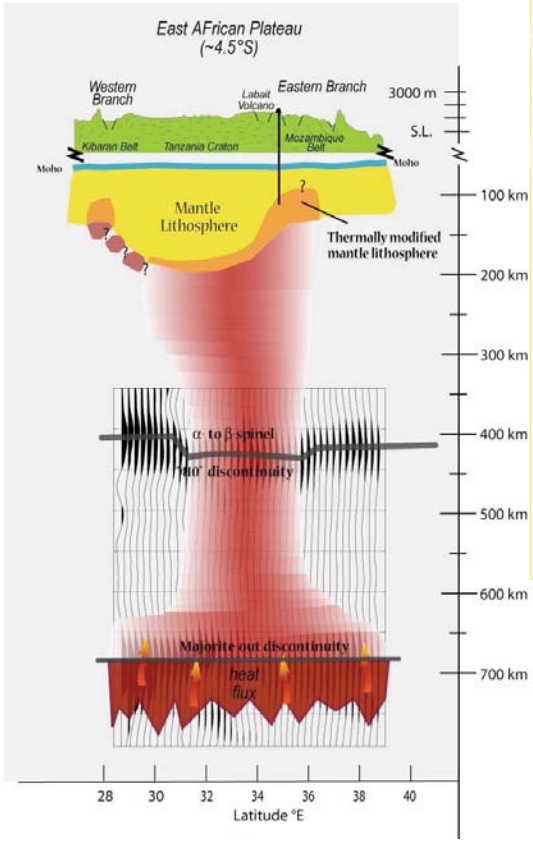


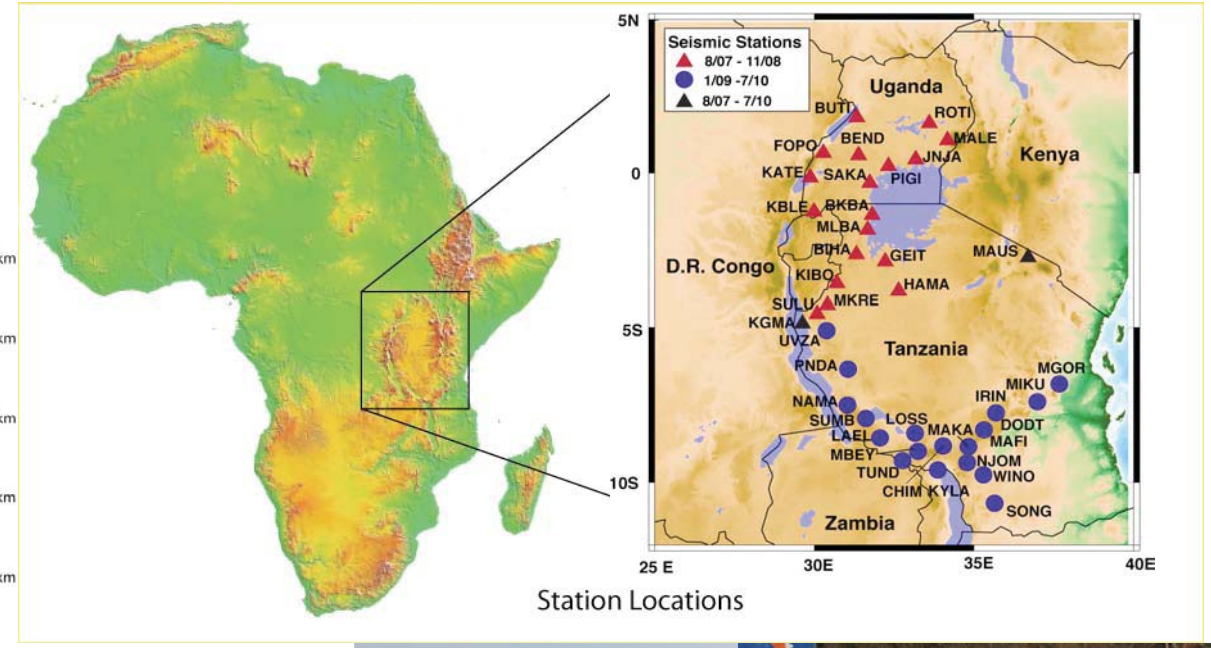



-4°
0°
-4°
-8°
Latitude
28°
32°
36°
40°
44°
Longitude
Mt Kenya
Mt Kilimanjaro
A
A'
B
B'
C
C'
D
D'
Depth to P410s discontinuity (km)
390
400
410
420
430
440
450
460
P410s absent

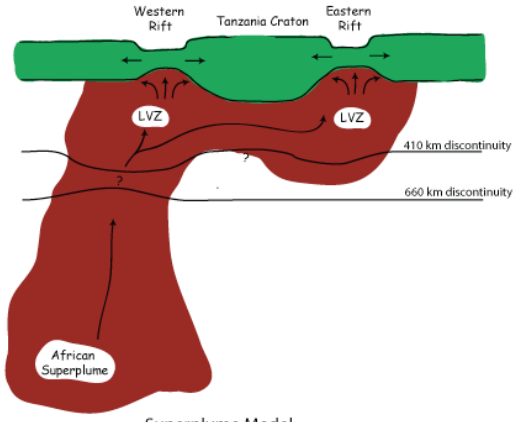

Upper-mantle plume
Second low viscosity zone
Lower mantle
Superplume
D'' Layer
CORE


East AFrican Plateau
(~4.5°S)
Western Branch
Labait Volcano
Eastern Branch
3000 m
S.L.
Kibaran Belt
Tanzania Craton
Mozambique Belt
Moho
Moho
Mantle Lithosphere
Thermally modified mantle lithosphere
100 km
200 km
300 km
400 km
500 km
600 km
700 km
α- to β-spinel "410" discontinuity
Majorite-out discontinuity
heat flux
28
30
32
34
36
38
40
Latitude °E

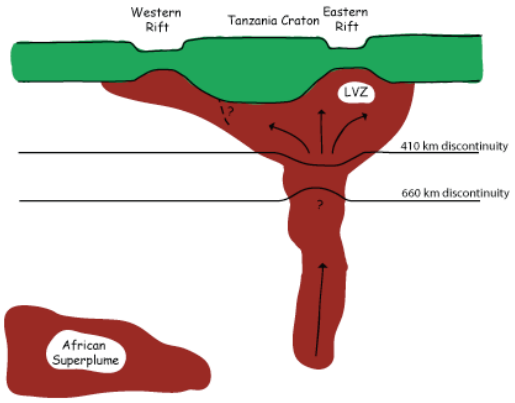




Station Locations



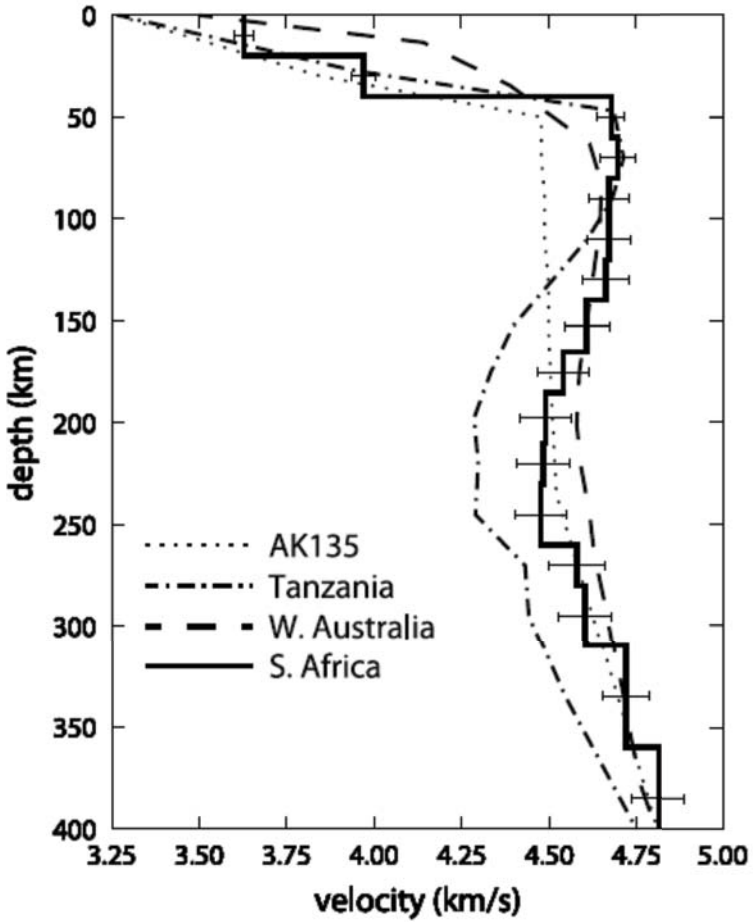
Superplume Model



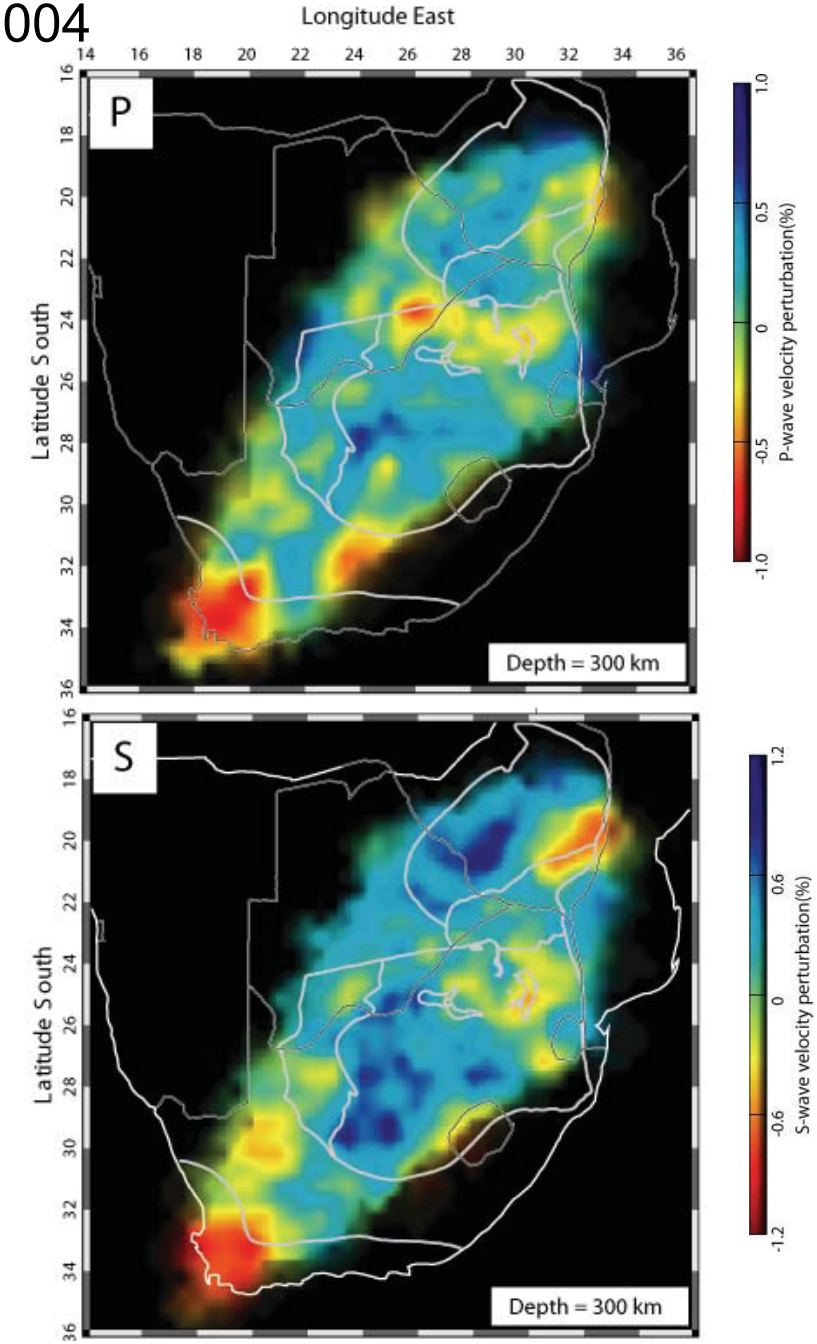
Mantle Plume

Southern Africa

Li & Burke, 2006



Fouch et al., 2004



AfricaArray - A public-private partnership supporting capacity building and research in the geosciences linked to Africa's natural resource sector

- to support in-situ training and research programs to help build a scientific workforce --initially in geophysics

- As part of the training and research programs, to create a network of shared scientific observatories (initially broadband seismic stations) for promoting education, research, and community building

- To support students from historically disadvantaged communities

"AfricaArray" = array of training programs + array of research projects + array of partnerships and collaborations + array of scientific observatories

Implementation for Africa (3 phases over 10 years) Phase 1 (years 1-3, started Jan. 2005)

- improve and expand the geophysics program at the University of the Witwatersrand, South Africa
- seismic stations installed or upgraded in participating countries as part of a permanent seismic network (southern and eastern Africa)
- data from the seismic stations used for student research
- data archiving at the IRIS (Incorporated Research Institutions for Seismology) data management center
- Develop a public-private funding partnership

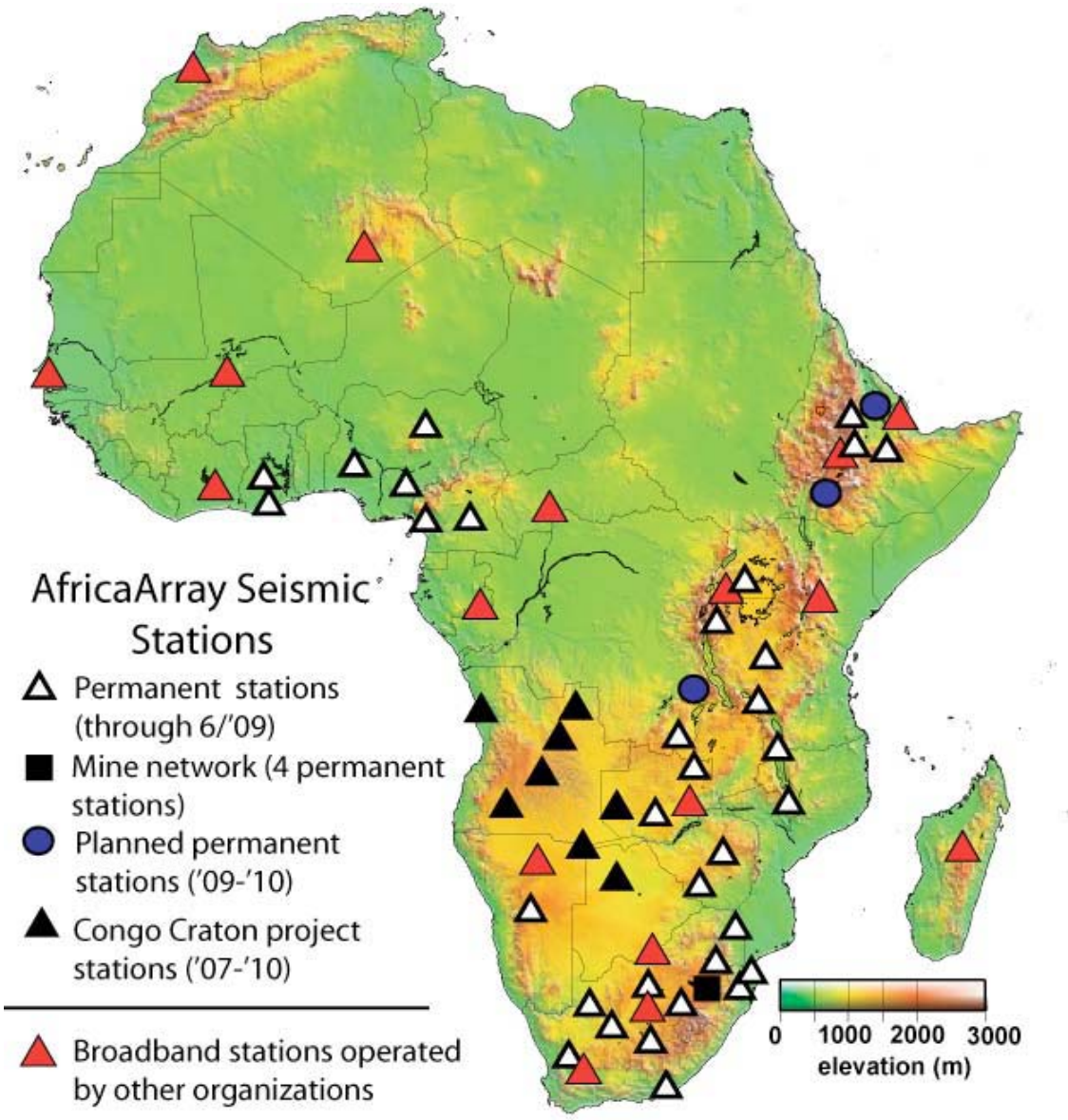
Implementation

Phase 2 (years 4-6) & Phase 3 (years 7-10)

- support centers of excellence in geophysics regionally at other African universities
- expand network of observatories and add other sensors (GPS, meteorological, hydrologic, other environmental sensors)
- expand educational and research activities into other science fields linked with the expansion of the observatory network

Progress so far

- Funding:
  - Gov't - NSF (US), DOE (US), NRF (S. Africa), DME (S. Africa), Belgium Gov't, in-kind support from many African gov't agencies
  - Industry - 19 companies
- Education:
  - 42 BSc honors, 17 MSc, 13 PhD, 5 Postdocs/Research Scientists
  - Research Chair in Seismology at Wits (5 yr post)
- Network:
  - 37 operational permanent seismic stations in 16 countries
  - 2 temporary networks (project-specific)
- Partners:
  - Universities in Africa 15
  - Universities in US and Europe 13
  - Gov't organizations in Africa 17
  - Gov't organizations outside Africa 8
  - companies 19
  - Academic and industry societies 6

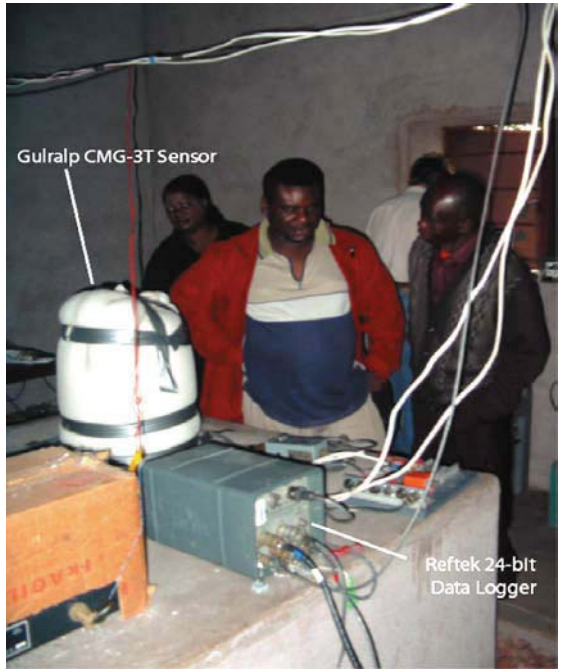


AfricaArray Permanent Seismic Stations

- 37 seismic stations
- 14 countries
- Continuous recording
- Data recovery 70-80%
- Data retrieval:
  - S. Africa - real-time using cell modems
  - Elsewhere - monthly

Kukurantumi,
Ghana

Itezhi-Tezhi,Zambia



Mzuzu, Malawi

Data Archiving and Access www.iris.edu/mda/AF (open data release for 2006 data begins in 2009)

IRIS DMC MetaData Aggregator

Usage

R = real time data available (access)
A = archive data available (access)

Network summary (1 time span)

Network AF :: Africa Array :: AF Network Map
Start Year 2005
End Year 2500

Stations for AF network 2005 to 2500 (29 stations)

	Station	Site	Latitude	Longitude	Elevation	First start	Last end
A	AAUS	Addis Ababa University, Ethiopia	9.04	38.77	2245	2006/01/10	2010/12/31
A	BFT	Belfast	-25.69	30.04	1868	2006/03/08	2599/12/31
A	BLWY	Bulawayo, Zimbabwe	-20.14	28.61	1348	2006/01/07	2010/12/31
A	CNG	Changalane	-26.29	32.19	100	2005/11/03	2599/12/31
A	CVNA	Calvinia	-31.48	19.76	1050	2006/05/11	2599/12/31
A	DESE	Dese, Ethiopia	11.12	39.63	2538	2006/07/27	2010/12/31
A	DODT	Dodoma, Tanzania	-6.19	35.75	1114	2007/02/11	2010/12/31
A	EKNA	Ekona, Cameroon	4.23	9.33	354	2007/01/23	2010/12/31
A	GRM	Grahamstown	-33.31	26.57	610	2006/05/11	2599/12/31
A	GSN	Windhoek, Namibia	-22.57	17.10	1728	2004/09/01	2010/12/31
A	HARE	Harare, Zimbabwe	-17.70	31.01	1501	2006/01/07	2010/12/31
A	HVD	Gariep Dam	-30.61	25.50	1433	2006/05/04	2599/12/31
A	KTWE	Kitwe, Zambia	-12.81	28.21	1227.6	2006/01/07	2010/12/31
A	LBB	Lubumbashi, DRC	-11.63	27.48	1283	2008/01/16	2010/12/31
A	MBEY	Mbeya, Tanzania	-9.00	33.25	1371	2008/02/06	2010/12/31
A	MBEY	Mbeya, Tanzania	-8.98	33.24	1331	2007/01/30	2008/02/05
A	MOPA	Mopani	-23.52	31.40	362	2006/11/11	2599/12/31
A	MZM	Mzuzu	-11.43	34.03	1258	2006/01/01	2599/12/31
A	PKA	Prieska	-29.67	22.76	960	2004/04/05	2599/12/31
A	POG	Pongola	-27.35	31.71	290	2005/03/04	2599/12/31
A	POGA	Pongola	-27.35	31.71	290	2006/03/30	2599/12/31
A	SEK	Senekal	-28.32	27.62	1486	2006/07/03	2599/12/31
A	SWZ	Schweizer Reneke	-27.18	25.32	1342	2006/01/31	2599/12/31
A	TEBE	Entebbe, Uganda	0.05	32.48	1132	2007/11/14	2010/12/31
A	TEZI	Itezhi-tezhi, Zambia	-15.75	26.02	1115.6	2006/01/10	2010/12/31
A	UPI	Upington	-28.36	21.25	845	2007/05/08	2599/12/31
A	UPI	Upington	-28.36	21.25	845	2006/06/22	2007/05/07